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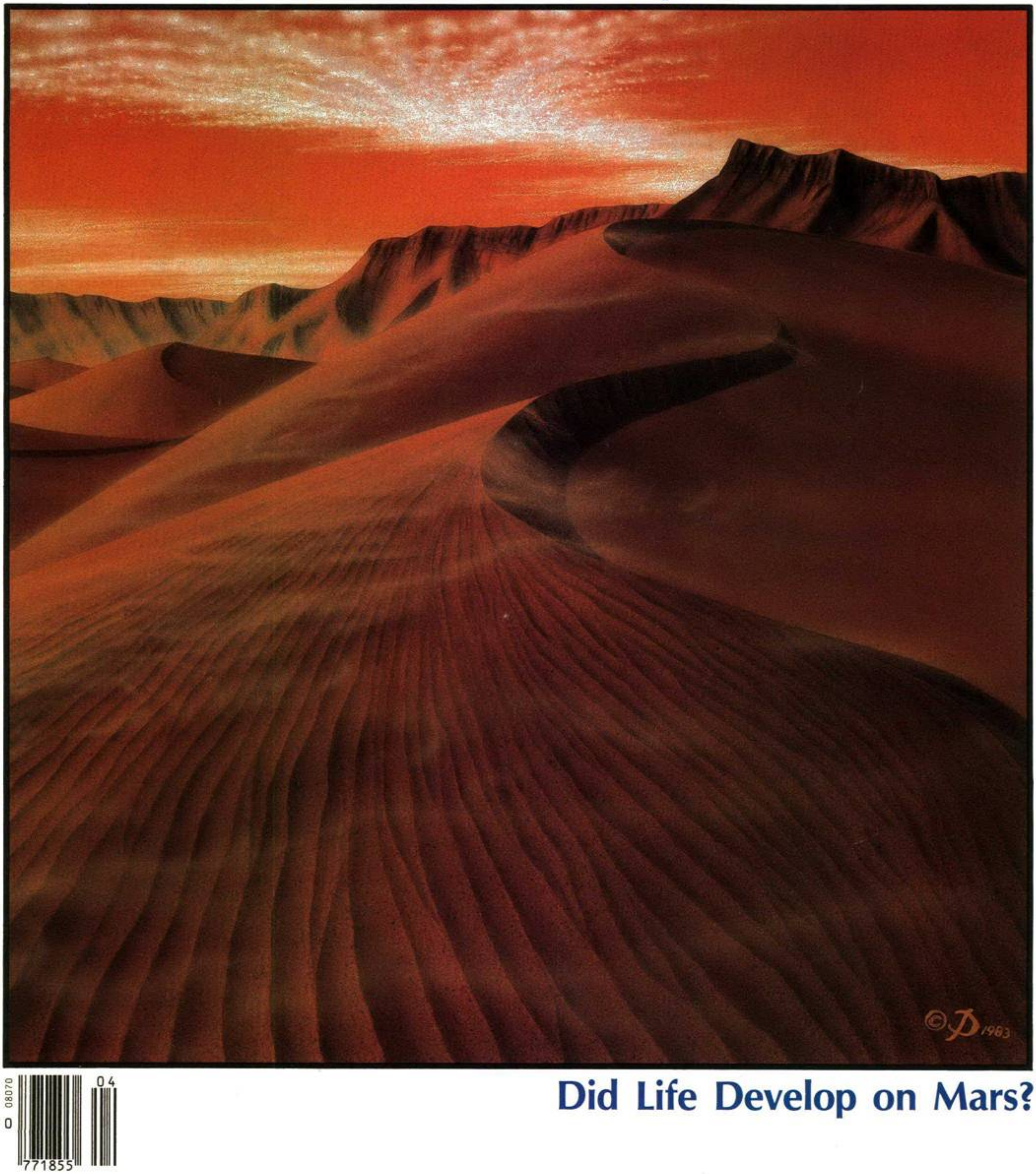

Did Life Develop on Mars?

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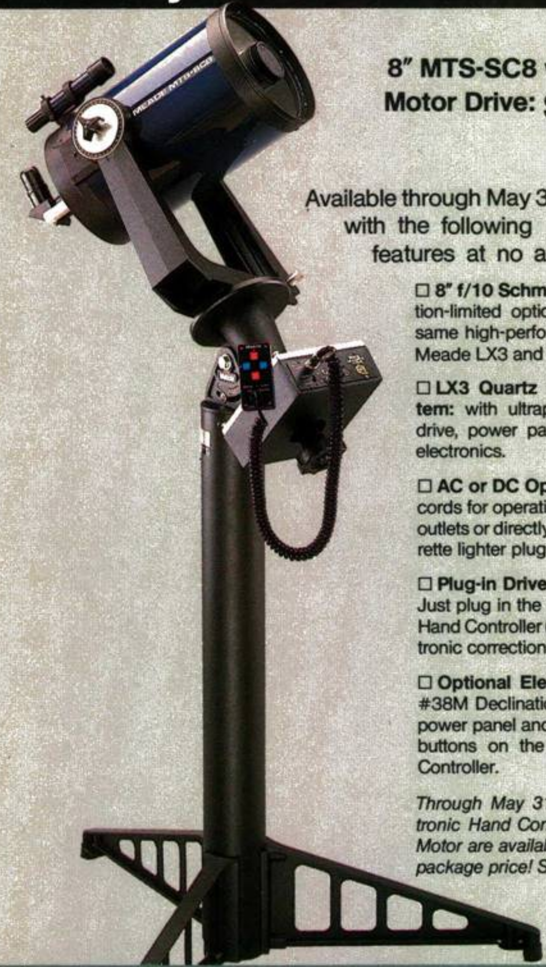

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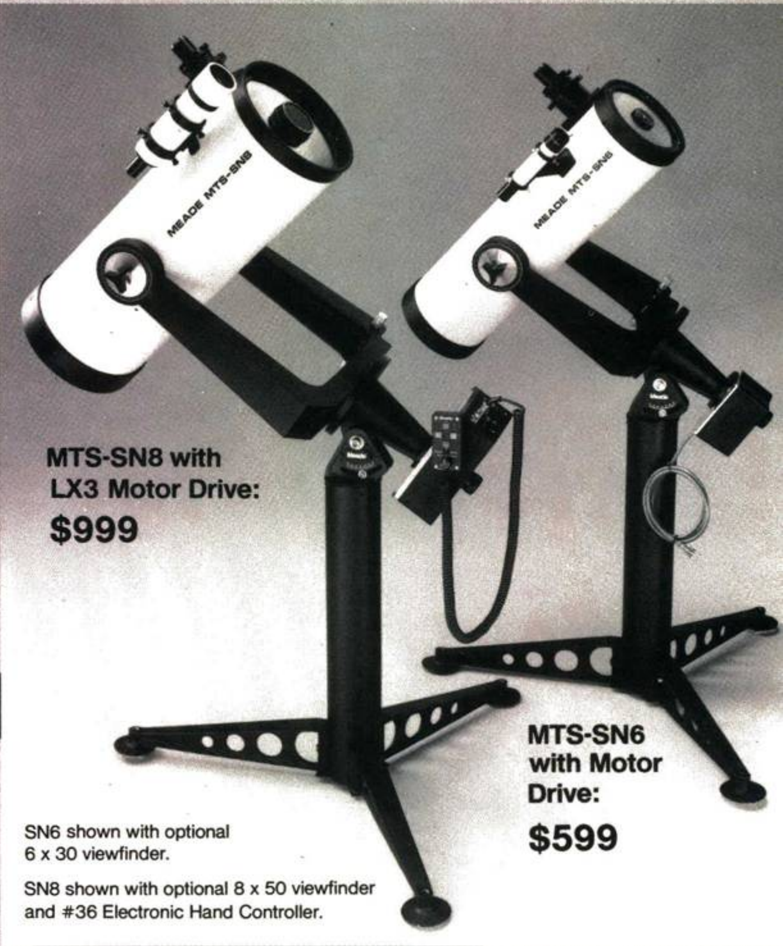

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SN6 shown with optional 6 x 30 viewfinder.

SN8 shown with optional 8 x 50 viewfinder and #36 Electronic Hand Controller.

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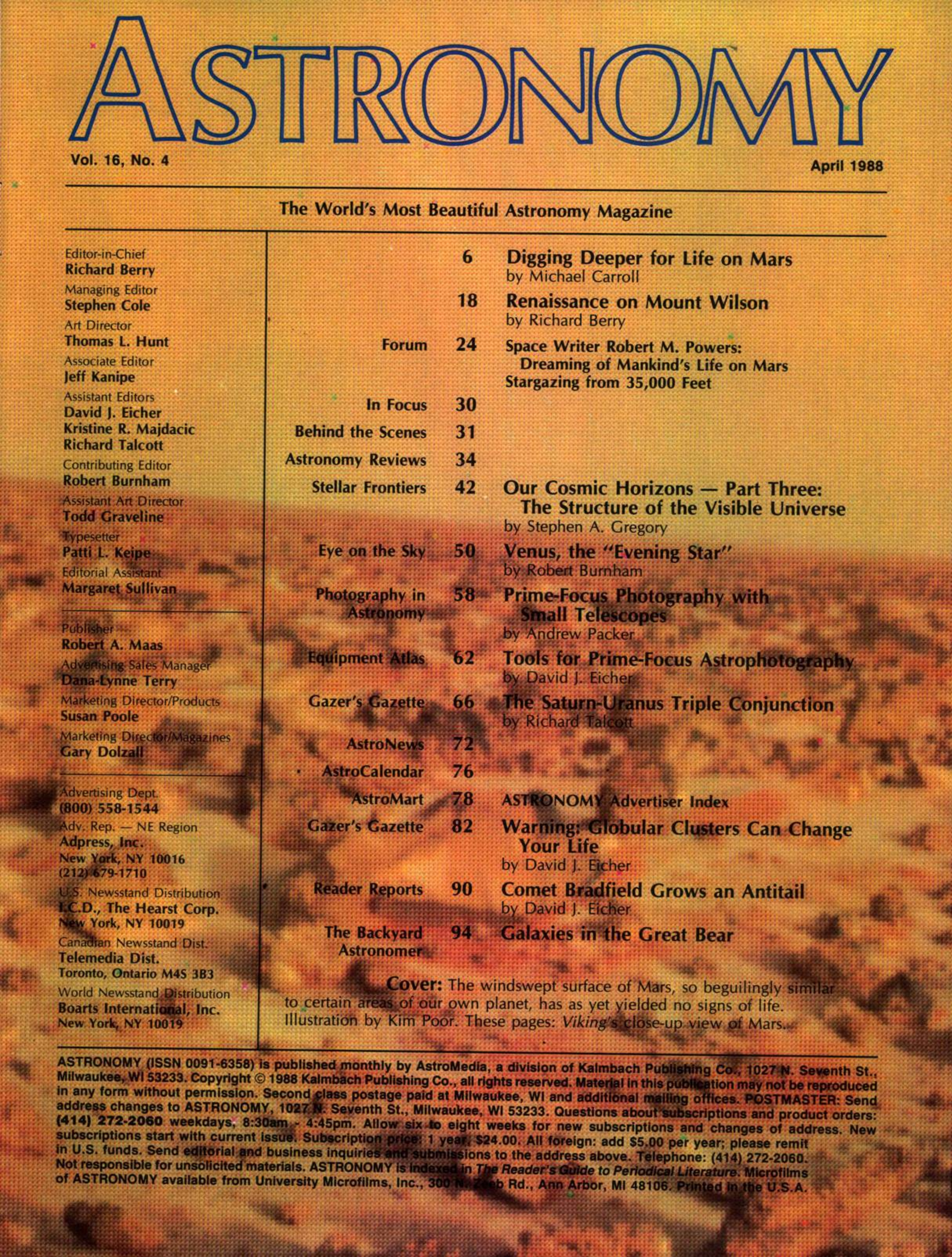

Cover: The windswept surface of Mars, so beguilingly similar to certain areas of our own planet, has as yet yielded no signs of life. Illustration by Kim Poor. These pages: *Viking*'s close-up view of Mars.

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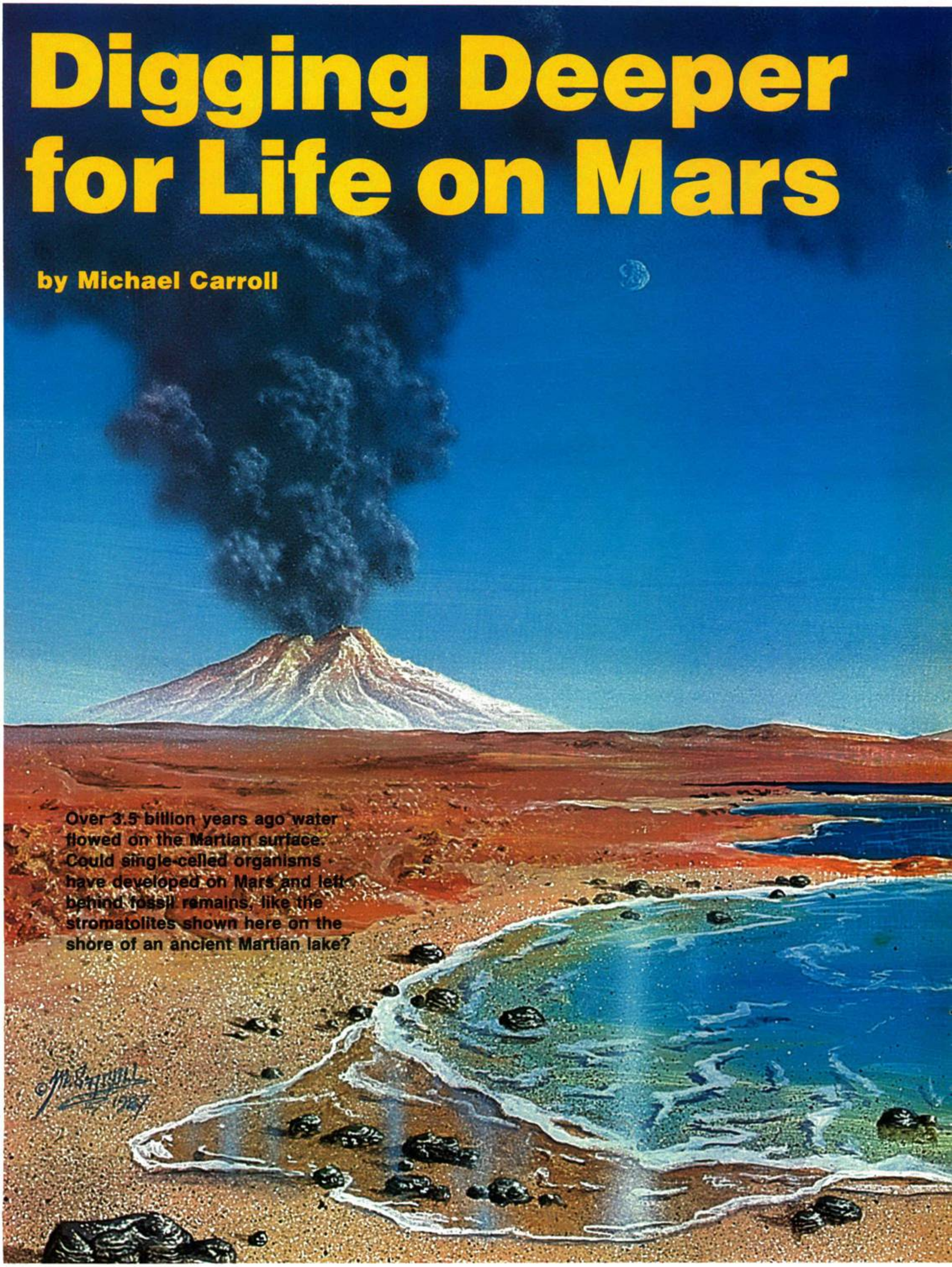
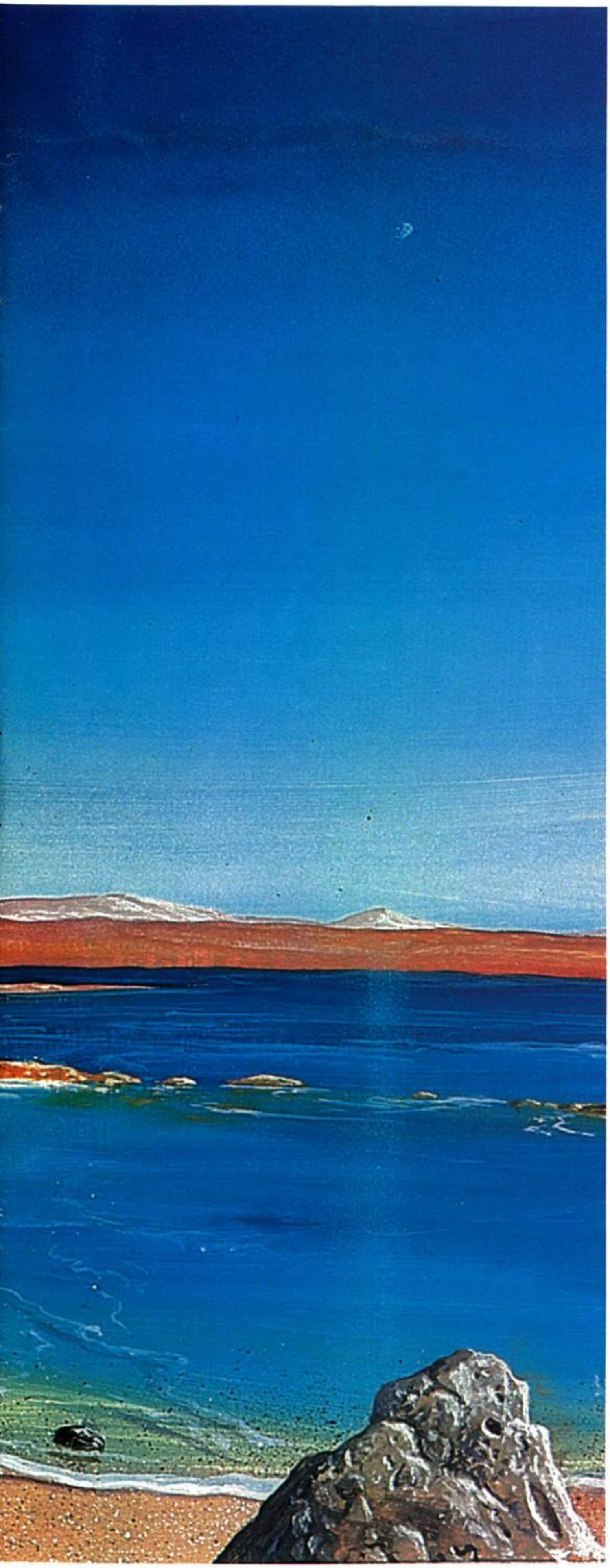
Digging Deeper for Life on Mars

by Michael Carroll



Over 3.5 billion years ago water flowed on the Martian surface. Could single-celled organisms have developed on Mars and left behind fossil remains, like the stromatolites shown here on the shore of an ancient Martian lake?



Michael Carroll

Some scientists believe evidence of life — either past or present — may be found when spacecraft return to the Martian surface in the 1990s.

Although astronomers have speculated about life on Mars for more than a century, they have discovered no intelligent creatures capable of interplanetary conquest, no artificial system of water-carrying canals, and no hardy microorganisms thriving in the surface soil. To many, the search for Martian life has reached a dead end.

But has it? Scientists continue to raise nagging questions that keep the controversial issue alive. Were the two sites where the *Viking* landers tested the Martian soil in 1976 representative of conditions on the entire planet? Are there other Martian locales more conducive to life? Could life be hiding below the surface? If there is nothing alive on Mars now, is there any fossil evidence of ancient life forms?

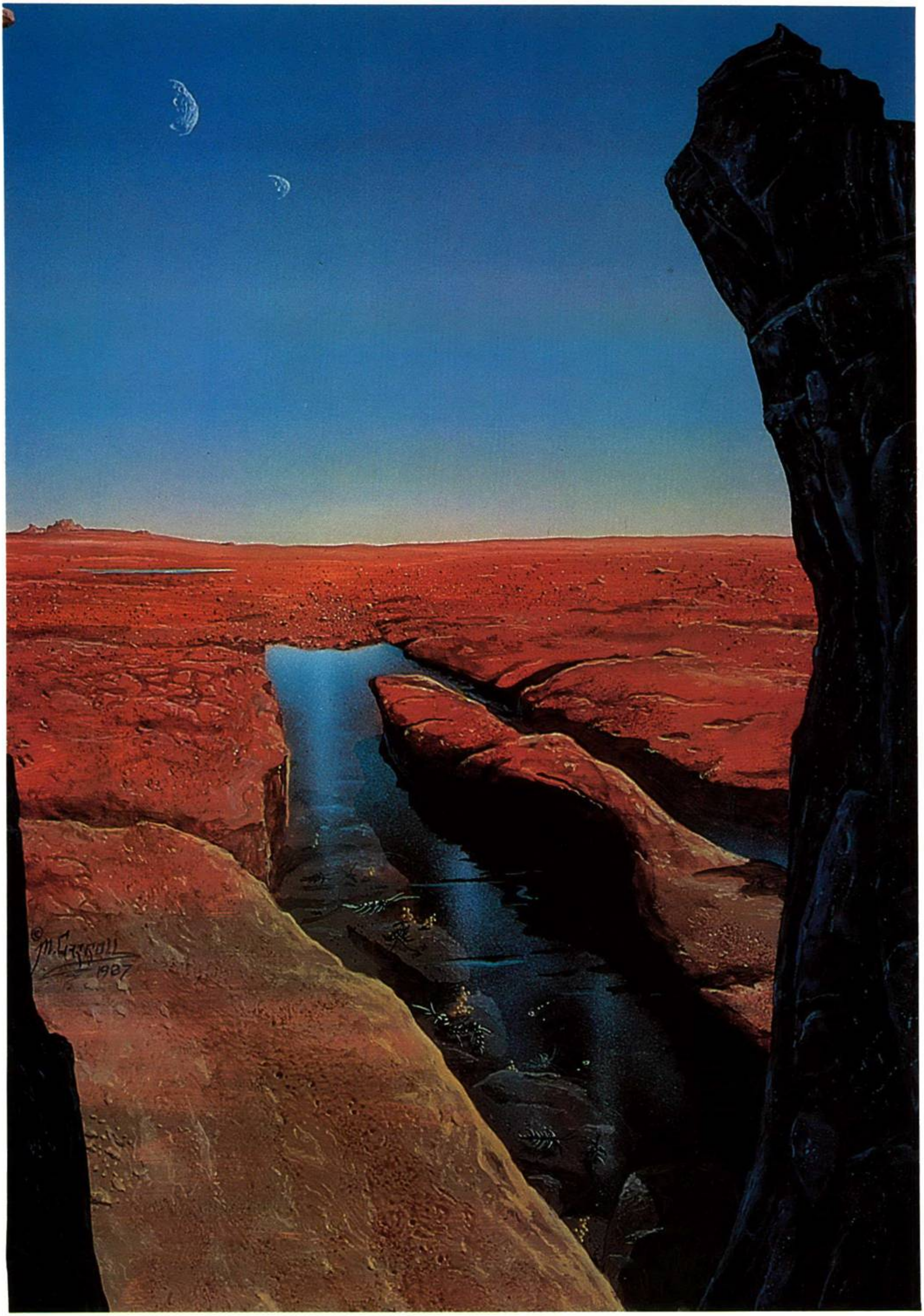
At the Case for Mars III conference held last July at the University of Colorado in Boulder, astronomers, biologists, and geologists from around the world discussed these questions and possible strategies for continuing the search for life on Mars. This summer the exploration of Mars resumes with the launch of the Soviet *Phobos* mission, to be followed in the 1990s by additional Soviet and American missions.

The fundamental assumption underlying continued interest in the possibility of Martian life is that, according to current theories on the evolution of the planets, Earth and Mars began their lives with very similar conditions. The two planets have clearly taken different paths since their formation 4.5 billion years ago, but if they were similar at one time, couldn't life have begun on both?

A Bleak yet Promising Planet

Our view of Mars after two decades of spacecraft observations reveals a planet that, as far as life is concerned, is at once bleak and promising. The current cold planet with its sparse atmosphere displays ancient surface features carved by liquid water. Consequently, the inhospitable character of the planet today cannot eliminate the possibility that life arose in a distant, more clement era.

Mars today is very cold and there is absolutely no liquid water. Although a summer day at the equator may heat up to a balmy 32° F, temperatures normally fall far below that. The Martian atmosphere is too thin — less than one hundredth that of Earth's — to hold much of the Sun's heat. (Being one-and-a-half times as far from the Sun as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Michael Carroll

As Mars gradually lost its atmosphere and the planet grew colder, any existing life forms may have retreated to small oases of water or, some scientists speculate, gone underground.

Earth is doesn't help either.) In the Martian winter much of the predominantly carbon dioxide atmosphere freezes and the polar caps grow larger.

But conditions on Mars during the planet's first billion years — the era in which life arose on Earth — were much different. The huge Tharsis Bulge covering nearly one quarter of the Martian surface is evidence of past volcanic activity that has now ceased.. The size and length of the valley networks carved into the heavily cratered terrain of the southern hemisphere bear witness to an era when large volumes of water flowed on the Martian surface.

According to Chris McKay, a biologist at NASA's Ames Research Center, "The environment on early Mars was comparable to the early Earth in all the biologically important parameters over a time period comparable to the origin of life on Earth." The presence of liquid water on the surface of Mars implies that the surface temperature was warmer than it is today and was accompanied by a higher atmospheric pressure. A much thicker carbon dioxide atmosphere has been proposed for early Mars.

These prebiotic conditions — surface water, a carbon dioxide atmosphere, moderate temperatures, and a high geothermal heat flow — are the same as those believed to have existed on early Earth. Notice that the conditions needed for life to begin are not necessarily the same as those that are needed to sustain life as we know it. Humans cannot live breathing carbon dioxide, but some early forms of life could not live without it. For life to begin, Earth must have undergone changes as major as those believed to have occurred on Mars.

The First Signs of Life

Our current understanding of how life emerged involves the gradual chemical evolution of increasingly complex molecules, which were the prerequisites for life. The four primary chemical ingredients of living things — hydrogen, oxygen, carbon, and nitrogen — form carbon-based, or organic, compounds. A small number of organic molecules called monomers make up the basic building blocks of life: amino acids, sugars, and fatty acids. Monomers join together to form long, chainlike molecules called polymers. DNA is a polymer that controls the reproduction process.

While the formation of complex organic molecules is only the first step in the development of life — organic molecules are not life itself because they are not self-reproducing — life cannot occur without these molecules. The conditions under which organic compounds can be formed set certain requirements on any life-producing environment. The extensive volcanic outgassing that took place in the early history of Earth, Mars, and Venus would have supplied an atmosphere composed of the necessary gases. Liquid water would furnish the medium in which chemical reactions could take place. The energy needed to drive the formation of organic molecules could have come from the Sun's ultraviolet light, lightning discharges, or radioactive elements in rocks.

In 1953 Stanley Miller, now at the University of California at San Diego, demonstrated that organic compounds could be produced in the laboratory given such conditions. He placed water in a glass bottle with a mixture of hydrogen, ammonia, methane, and water vapor to simulate the composition of one possible atmosphere on the primordial Earth. Miller then passed sparks through the mixture. After several days complex organic molecules, including amino acids, were found in the water.

But the formation of organic compounds does not automatically lead to life. These organic materials have been synthesized in places besides Earth. "We have found amino acids in the pristine cores of meteorites like the Murchison meteorite," explained Miller. "What this shows is that while we don't know in detail what happened on the early Earth, since most of the ancient rocks have been destroyed, we see that it happened on the parent body of these meteorites."

Life is based on an extremely complex chain of events that could, if conditions take a wrong turn, end at many points. Even if life gained an initial foothold on Mars, there is no certainty life got very far. "There is an incredible diversity of things going on at the cellular level," said Denis Patrick, molecular and cellular biologist at the Salk Institute of Biotechnology/Industrial Associates. "Any break of any link in that chain causes the whole thing to come to a screeching halt. All the DNA and RNA and amino acids have to work in concert."

When Evolutionary Paths Diverge

Clearly at some point Mars and Earth took different evolutionary paths as planets. Earth went from a carbon dioxide-rich atmosphere to an oxygen-rich atmosphere and developed a protective layer of ozone that keeps out

Mars and Earth were, in their first billion years, very similar: extensive volcanic activity produced the early atmospheres of both planets. Mars, however, lost its atmosphere as volcanic activity gradually ceased on the planet.

solar ultraviolet light. Mars gradually lost its thick atmosphere and grew colder. What happened?

On both Mars and Earth the carbon dioxide in the atmosphere was converted by reactions in water into carbonate rocks. The supply of carbon dioxide was replenished, however, by the volcanic recycling of carbonate rocks into gas. (See diagrams on page 11.) The extensive tectonic activity on Earth kept this recycling process going and the atmosphere was maintained. But there is no evidence of plate tectonic activity on Mars that would have kept the crustal rocks recycling. Mars, a planet only half the diameter of Earth, did not have sufficient internal heat flow to sustain tectonics. Consequently, it slowly lost its atmosphere as carbon dioxide was locked into the rocks.

But for a billion years or so, before the two planets went their separate ways, Earth and Mars had significant similarities. Did they also share life? Did complex organic molecules develop on Mars? Did single-cell, carbon dioxide-breathing bacteria evolve on Mars as they did on Earth? Did life advance to a multicellular level and achieve photosynthesis?

Chris McKay has proposed three possible scenarios for the history of biological development on Mars: 1) life began on Mars as it did on Earth and remained for 1 billion years or more; 2) prebiotic evolution occurred and possibly primitive organisms developed but conditions deteriorated and life ceased; 3) prebiotic evolution never occurred on the planet. Of this wide range of possibilities, direct biological experiments conducted on Mars primarily examined the least likely option: active life.

The twin *Viking* landers carried three experiments devoted to detecting current biological activity and one to detect organic compounds. To detect biological activity, Martian soil samples were treated with various nutrients that would produce characteristic by-products of biological metabolism if life forms were active in the soil. The results were inconclusive. Another experiment heated a soil sample to look for signs of organic material but found none, an unexpected result because at least organic compounds from the steady bombardment of the Martian surface by meteorites were thought to have been present. The absence of organic materials is apparently the result of intense ultraviolet radiation penetrating the largely ozone-free atmosphere of Mars and destroying organic compounds in the soil.

From a biologist's point of view, "*Viking* was pretty bad news all around," said McKay. "For starters there is no organic material in the soil samples. There are very low nitrogen levels. There is ultraviolet radiation."

Viking Mission the Final Word?

But there are researchers who point out that the *Viking* results cannot be considered the final word on Martian life because the landers only sampled two limited — and uninteresting — sites. The *Viking* landing sites were not chosen for what they might tell of the planet's biological past. They were chosen primarily because they appeared to be safe for landing a spacecraft. The landing sites were on parts of the Martian plains that appeared relatively featureless from orbital photographs.

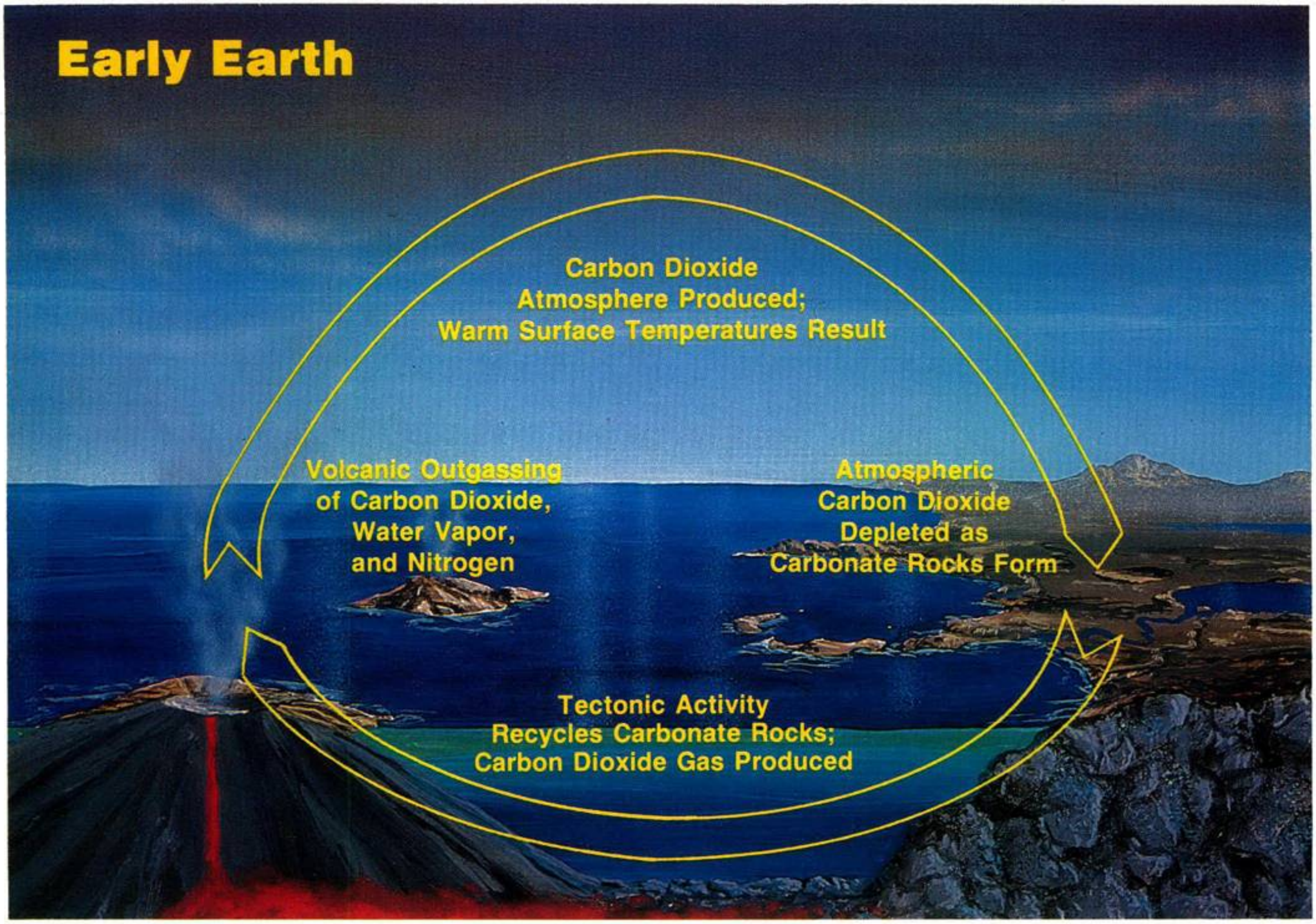
Two types of Martian terrain, which have parallels on Earth that currently support life, are put forward by some researchers as possible hiding places for active Martian life. The ice-free region of southern Victoria Land, Antarctica, contains dry valleys where temperatures average below zero. Microorganisms have been found in this region inside sandstone rocks and under the ice of frozen lakes.

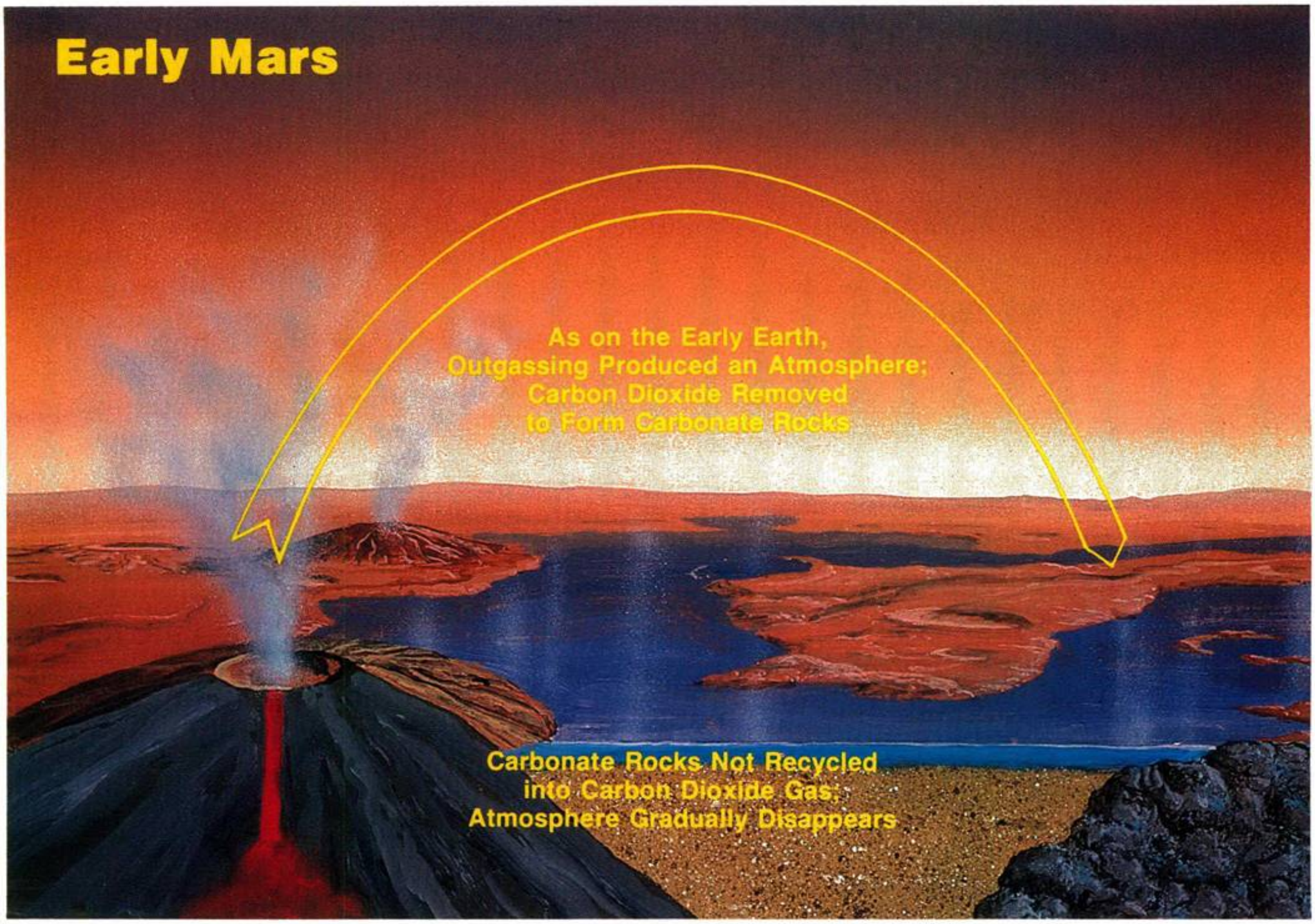
"How can people say that nothing could have survived the Martian cold," said Gil Levin, designer and principal investigator of one of the *Viking* biology experiments. "Mars has not gone through any more dramatic changes inimical to life than the Earth has. For example, when that ultimate poison, oxygen, appeared, life managed to hold on here."

Scientists in the Soviet Union seem to agree that active life could still be found on Mars, but they suggest that we look well below the surface. In a teleconference between Soviet and U.S. Mars researchers sponsored by the Planetary Society during the Case for Mars conference, Soviet scientists expressed a strong interest in searching for Martian life within a possible water-saturated zone on top of the subsurface permafrost layer.

"*Viking* results cannot be regarded as the last word [on Martian life]," said Lev Mukhin of the Soviet Institute for Space Research, "since *Viking* did not get a total, final answer about the absence or presence of life on Mars."

Mikhail Ivanov, director of the Soviet Institute for Microbiology, would search for oases of life on Mars. "One of the main such targets should be the subsurface layers below the soil," Ivanov said during the teleconfer-


Early Earth
Carbon Dioxide Atmosphere Produced; Warm Surface Temperatures Result
Volcanic Outgassing of Carbon Dioxide, Water Vapor, and Nitrogen
Atmospheric Carbon Dioxide Depleted as Carbonate Rocks Form
Tectonic Activity Recycles Carbonate Rocks; Carbon Dioxide Gas Produced


Early Mars
As on the Early Earth, Outgassing Produced an Atmosphere; Carbon Dioxide Removed to Form Carbonate Rocks
Carbonate Rocks Not Recycled into Carbon Dioxide Gas; Atmosphere Gradually Disappears

Michael Carroll

The *Viking* landers that dropped to the Martian surface in 1976 did not detect signs of active life in the Martian soil. Future missions will take another look with robotic rovers that will bring samples to Earth.

ence. "Various types of brines and solutions found inside Mars might also be a suitable environment in which to look for life. These ecosystems on Earth are inhabited quite densely and quite constantly, so the question of the existence of possible oases on Mars should not be ruled out."

Soviets Plan to Dig In

Soviet mission planners have begun to work on the problem of reaching those subsurface layers. "Obviously one has to get to the permafrost in order to respond to the question of whether there are any forms of life on Mars," said Yuri Surkov, a Soviet expert on space chemistry. "We are thinking hard about what kind of device [we] ought to have to penetrate several tens of meters underground."

McKay, who has studied microbiology in the Antarctic dry valleys, disagrees with those who hold out hope for active life on Mars. "All life on Earth requires water. I have studied the polar plateau and the Greenland ice sheet — these places are a picnic compared to Mars. There are no organisms there except at the boundaries where liquid water exists." McKay submits that when water froze and boiled away with the disappearing Martian atmosphere, any life would have become extinct. "My conclusion, unfortunately, is that there's just no chance [of current Martian biology]. The facts just force me to the conclusion that 'It's dead, Jim.'"

McKay and others believe the problem with finding active life on Mars is not a matter of looking in the wrong places but at the wrong time. McKay, who is working on the plans for a future U.S. Mars rover/sample return mission, suggests we should return to Mars in search of fossils. Paleobiology — the study of ancient life forms — may be moving out into the cosmos.

The fossil record on Earth stretches back 3.5 billion years. Biologists believe life started well before then because the fossils from that time have been those of fairly advanced organisms. "At 3.5 billion years ago, filamentous microbes had already evolved," said Stanley Awramik of the University of California at Santa Barbara. Awramik has discovered several of the most ancient fossils of primitive life. He submits that the complexity of the fossils indicates life probably began quite some time before these creatures were fossilized.

If McKay's first scenario occurred and life developed on Mars, survived for at least 1 billion years, and achieved a fair degree of microbiological sophistication, future exploration of the planet might find stromatolites, layered rocks made from colonies of blue-green bacteria living at the boundaries between water and sediments. Stromatolites were widespread over the Earth 2 billion years ago.

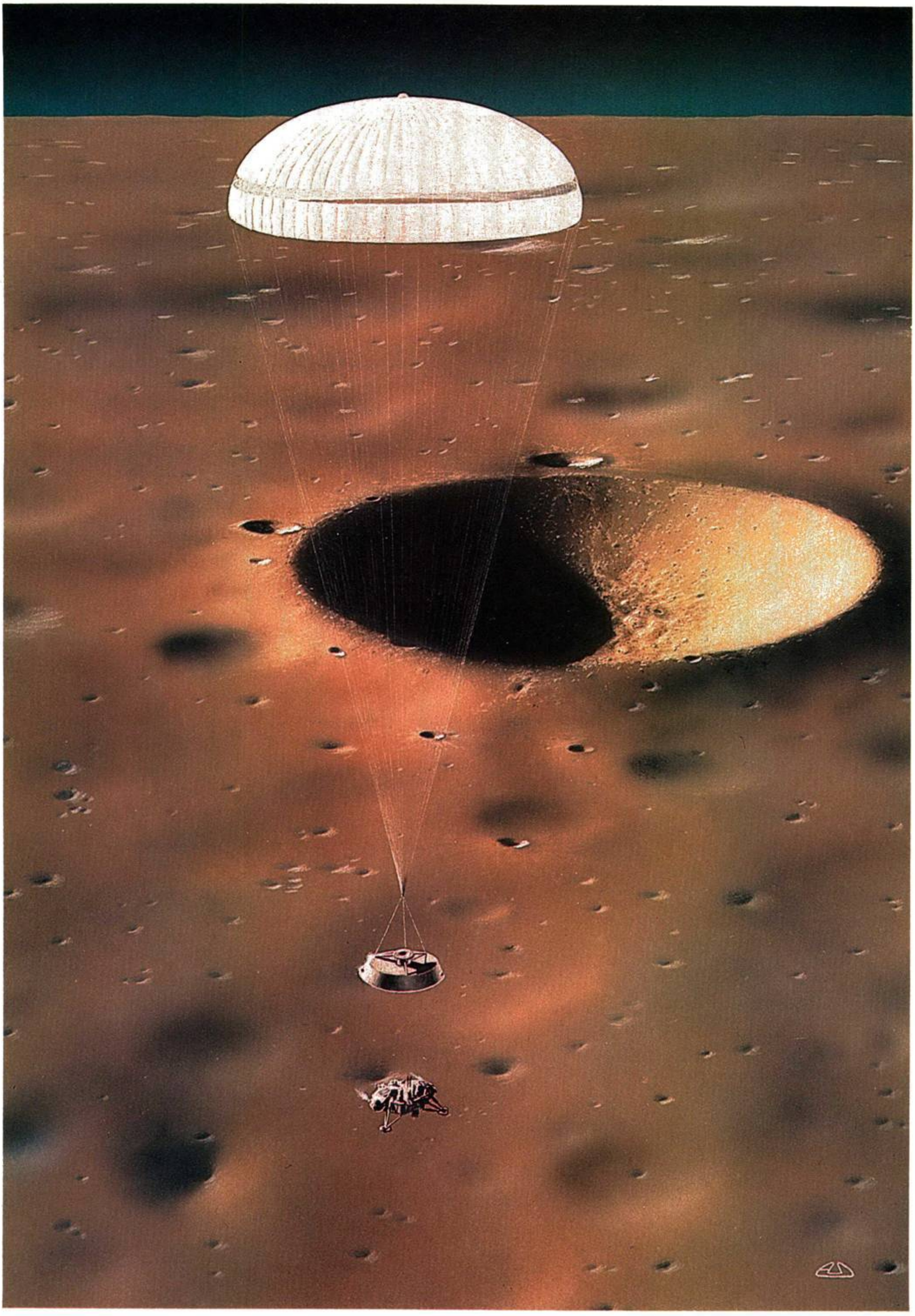
The search for Martian stromatolites and fossils will not be an easy task, warned Awramik. "The fossilization of microscopic organisms is a capricious and selective process. Even under the best preservational conditions most microbes are not preserved. There are only two occurrences of microfossils from Earth's oldest terrains, although several tens of occurrences are known from rocks upwards of a billion years younger. On Earth even the most experienced scientist searching strata preserved under the best of geological conditions rarely finds fossils in Earth's oldest rocks. What are the chances of success on Mars?"

Martian Fossils Preserved

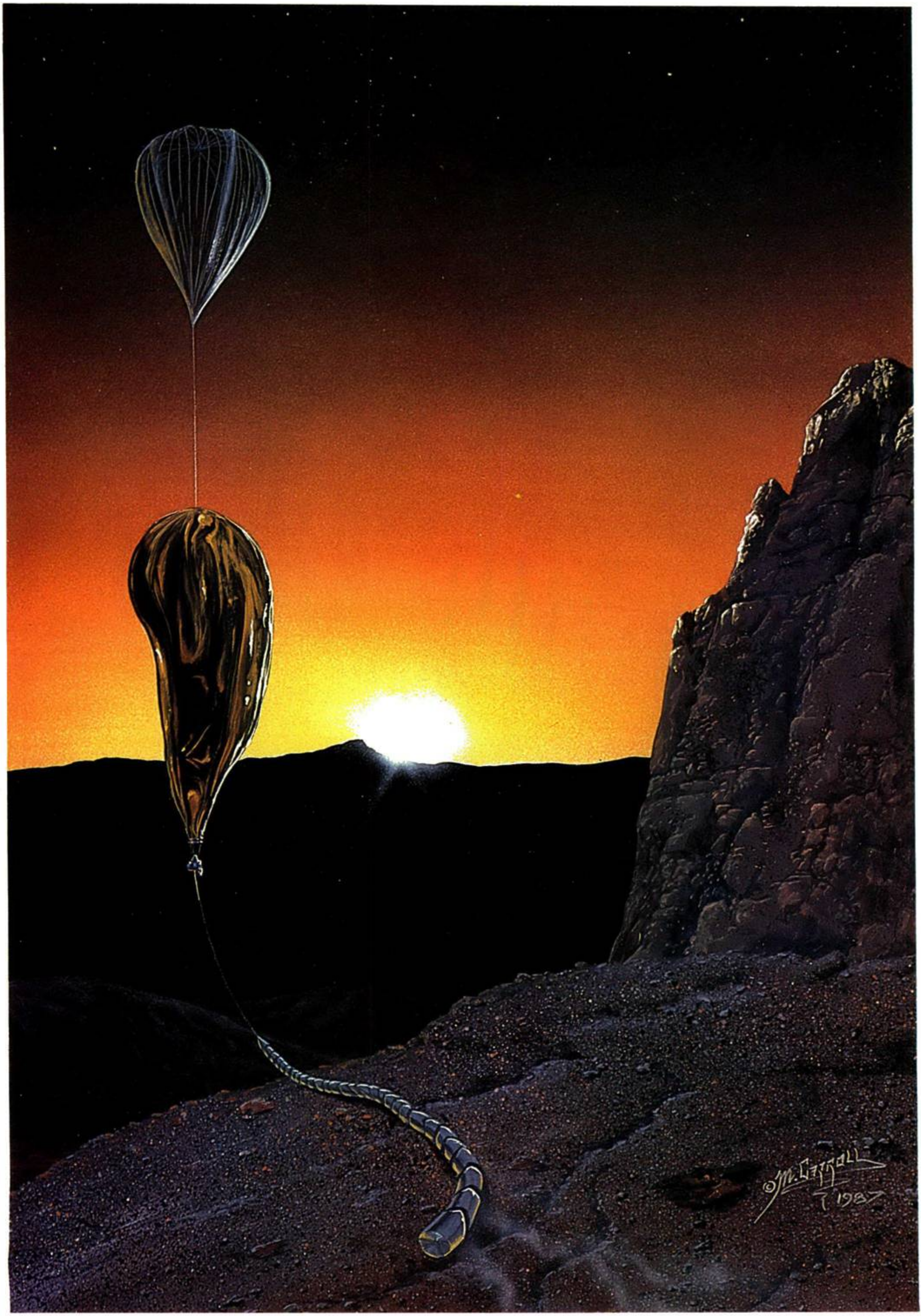
The search for fossils on Mars has one thing working in its favor that searches on Earth don't: erosion and plate tectonics have destroyed much of the ancient fossil record on Earth. But Mars seems to have low erosion rates and no plate tectonics. If life arose within a primordial epoch on the Red Planet, some geologists feel Mars could have preserved a record of it. Deep beneath the golden sands of Mars may be the best record of events that occurred on the terrestrial planets in the early ages of the solar system.

The search for that record will be an exciting one, and one that is within our grasp. Both the United States and the Soviet Union are preparing Mars missions that will return samples to Earth. The Soviet Union has already expressed its intention to mount a robotic Mars sample-return mission, perhaps during the 1998 launch opportunity. No timetable has yet been set for a U.S. mission.

While NASA's *Mars Observer* mission in 1992 will produce a global picture of surface composition and high-resolution photos of the terrain that will help with site selection, it will not directly explore Mars for signs of life. An automated surface rover, however, could be directed to areas that appear to be ancient lake beds or beach terrain, sites where water was present in the first billion years of Martian history. There the robot could seek the same types of samples known to contain microfossils here on



Adolf Schaller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Michael Carroll

The Soviet Union plans to survey Mars with this French-designed balloon that will drag instruments over the surface. Solar energy inflates the lower balloon at sunrise, lifting it into the atmosphere where it floats to another location until sunset, when it descends to the surface.

Earth. If the rover were advanced enough, microscopic imaging could be carried out on site. The rover could also load the samples aboard a vehicle for return to Earth.

A rover mission would be much more complex and difficult than the *Viking* mission, according to Roger Bourke of the Jet Propulsion Laboratory. "Several things make it difficult to send this thing rolling across the landscape. First, there are large light-time delays: the time required to see what the rover sees and to command the rover to do something about what it sees may be a matter of minutes to nearly an hour. So it's impossible to tell the rover what to do quickly.

"Second, the environment is quite unknown. Terrain on the scales relative to a rover are known only in two sites, namely the two *Viking* lander sites," Bourke said. "We will get resolutions of a few meters in small areas from *Mars Observer*. We also hope to get good data from the Soviet Mars mission in 1992, which will have balloons and possibly a rover."

Field Geology on Mars

But there are limits to what even a sophisticated automated rover will be able to accomplish on Mars, according to Steven Squyres of Cornell University. "An autonomous rover could run the risk of committing one of the worst errors imaginable for a mission of exploration: ignoring an unexpected discovery because it was not programmed to respond to some unexpected stimulus."

Ultimately, good geological work on Mars as on Earth will require humans. "The advantages of manned exploration stem from the adaptability of humans and the human ability to do sophisticated data analysis and assimilation of observations on Mars rather than remotely," said Squyres. "The human brain is uniquely suited to processing large amounts of information and making judgments based on that information. In place in the environment and with the proper equipment the human mind can make observations, formulate and test hypotheses, and reach conclusions with unmatched efficiency."

And when it comes to fixing things, Squyres pointed out, nothing beats human ingenuity. "Another important advantage of humans over rovers is that humans have a much greater capacity for solving problems and repairing malfunctioning equipment. Any geologist who has worked in a remote, hostile environment realizes what a large effort is expended on fixing even the best-designed equipment overtaxed by its environment."

The only geologist who has done field work on another world agrees. "This is something that cannot easily be done with robots," said Harrison Schmitt, who spent three days on the Moon as a crew member of *Apollo 17*. "You need somebody standing there, seeing the problem. Ancient microfossils are rare and in unusual enough environments that human intuition is required."

No matter what evidence of life that robot and manned missions may uncover on Mars — even if no signs of life are found — scientists will better understand how life arises and evolves. The discovery of active life on Mars would clearly expand our ideas of the conditions under which life can survive in the universe.

If no active life is found but only relics of the very early stages of biological evolution, we may be able to see a stage of the evolutionary process not found on Earth. The record of the earliest stages of life on Earth has vanished, recycled into the crust. "It is entirely possible that even if no life exists on Mars today, Mars holds the best record of the chemical and biological events that led to the origin of life and its early evolution," said McKay.

"Mars represents an arrested stage in planetary development," said Schmitt. "If life became extinct, it further limits that narrow thermal and chemical band around a star where life can exist. These are insights we cannot possibly gain from Earth."

And if McKay's third scenario is proved true — that life never existed on Mars — scientists will have to change their views about the preconditions for life. "It's the old Sherlock Holmesian inductive logic that 'the dog did nothing in the nighttime,'" said Schmitt. "Even though the dog did nothing, that fact proved valuable in solving the case."

If no traces of life are found on Mars, what made the Earth different enough that living things could inhabit this special place and not our neighbor Mars? The answer to this question may have a more profound effect on the scientific perspectives of humankind than any other single event of this century.

Michael Carroll is an astronomical artist and freelance writer who lives in San Diego, California. His most recent article for ASTRONOMY, "The Changing Face of Mars" in the March 1987 issue, also featured several of his illustrations.

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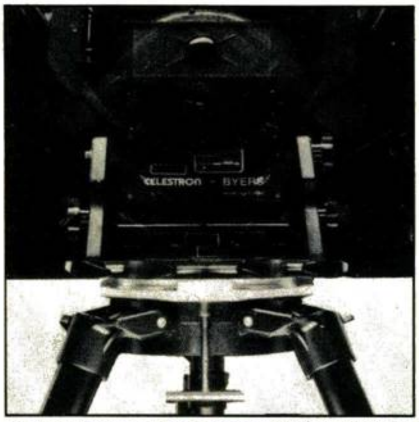

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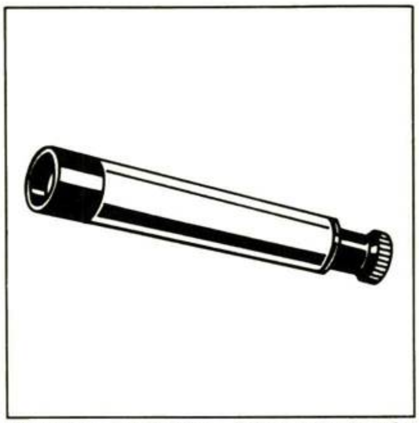

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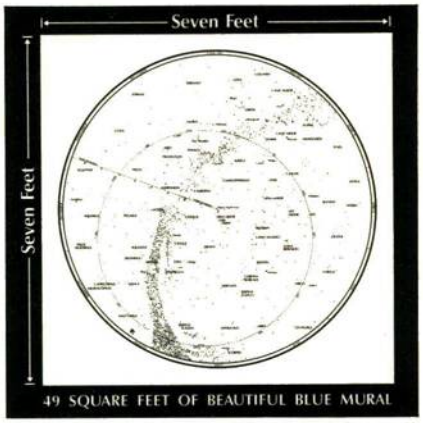

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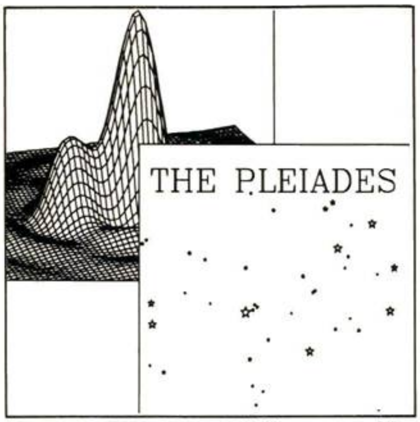

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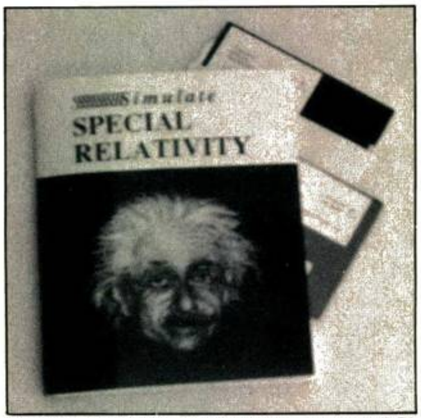

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Renaissance on Mount Wilson

by Richard Berry

Under new management, Mount Wilson Observatory promises continued research and greater public involvement.

"It's the best telescope in the world for some kinds of astronomy," said Arthur Vaughan, chairman of the Board of Trustees of the Mount Wilson Institute. "The 100-inch Hooker telescope on Mount Wilson offers a large aperture and a very large number of clear nights per year, and it's going to be available for decades to come."

Two years ago the Carnegie Institution of Washington shut down the Hooker telescope. But this summer the Mount Wilson Institute hopes to reopen the historic instrument and take over the operation of Mount Wilson Observatory. The institute will operate and refurbish the telescopes, administer research, and foster public involvement in astronomy.

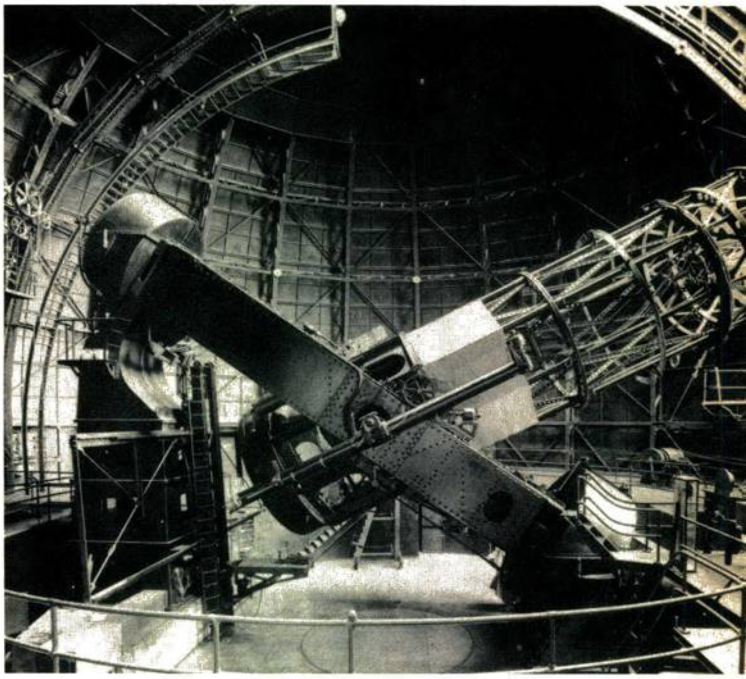
From the decade preceding World War I until the end of World War II, Mount Wilson Observatory was the astronomical center of the world. While three powerful solar telescopes revealed the Sun's magnetic storms, astronomers studied the spectra of stars and nebulae with the observatory's 60-inch reflector and, following the completion of the 100-inch telescope in 1917, pioneered extragalactic astronomy.

Less than ten years after it opened, the 100-inch telescope showed beyond a shadow of doubt that "spiral nebulae" were galaxies much like our own Milky Way and at enormous distances from Earth. By the eve of World War II, astronomers working with the 100-inch telescope had established the expansion of the universe that laid the observational groundwork for the Big Bang theory.

Closing Down the 100-inch

The announcement that the 100-inch telescope would be "moth-balled" in June 1985 came as a double shock. Not only was the telescope historically significant, but it was still a fully functional large instrument located at a site with very good seeing. Besides, it was engaged in important astronomical research. Furthermore, the Carnegie Institution of Washington, the owner, considered closing the entire observatory to channel money into other projects.

Since 1904, when industrialist Andrew Carnegie granted $600,000 to observatory founder George Ellery Hale, the Carnegie Institution had operated Mount Wilson Observatory (see "Reach for the Stars: The Story of Mount Wilson Observatory" by Joseph M. Horodyski, December 1986). For the 1980s, however, Carnegie had decided to concentrate its resources on the operation of the Las Campanas Observatory in Chile and on the construction of an 8-meter telescope there.



Above: The 100-inch Hooker telescope on Mount Wilson opened the universe for humanity, but it was shut down in 1985. It will open again for research under the management of the Mount Wilson Institute. Photograph courtesy of the Carnegie Institution of Washington.

Opposite page: Arthur Vaughan, head of the Board of Trustees of the Mount Wilson Institute, believes the 100-inch Hooker telescope (background) is still the finest telescope in the world for high-resolution astronomical research.

The Carnegie Institution didn't want to close the Mount Wilson site down, but it couldn't afford to keep the observatory open and develop a Southern Hemisphere site too. Because the programs on the solar telescopes and the 60-inch telescope received funding from the National Science Foundation, NASA, and the Office of Naval Research, these programs were allowed to continue. But the programs on the 100-inch, which Carnegie itself had funded, were not. Carnegie moth-balled the 100-inch telescope and started looking for someone else to run the observatory.

Wanted: An Observatory Operator

What the Carnegie Institution needed was an operator: a responsible party to take over the observatory. None of the researchers working at the observatory would have been able to handle the job alone, because it was too big for any individual. An umbrella organization — a consortium of astronomers, universities, and businesses with the knowledge, talent, and money to operate a world-class astronomical observatory — was needed.

In February 1986 the Mount Wilson Intitute was born in the minds of astronomers Arthur Vaughan, Roger Ulrich, and Edward Rhodes. "Before we got the public and the business community involved," said Vaughan, "we were just a bunch of frustrated astronomers."

On September 17, 1987, the executive committee of the Carnegie Institution's Board of Trustees announced its

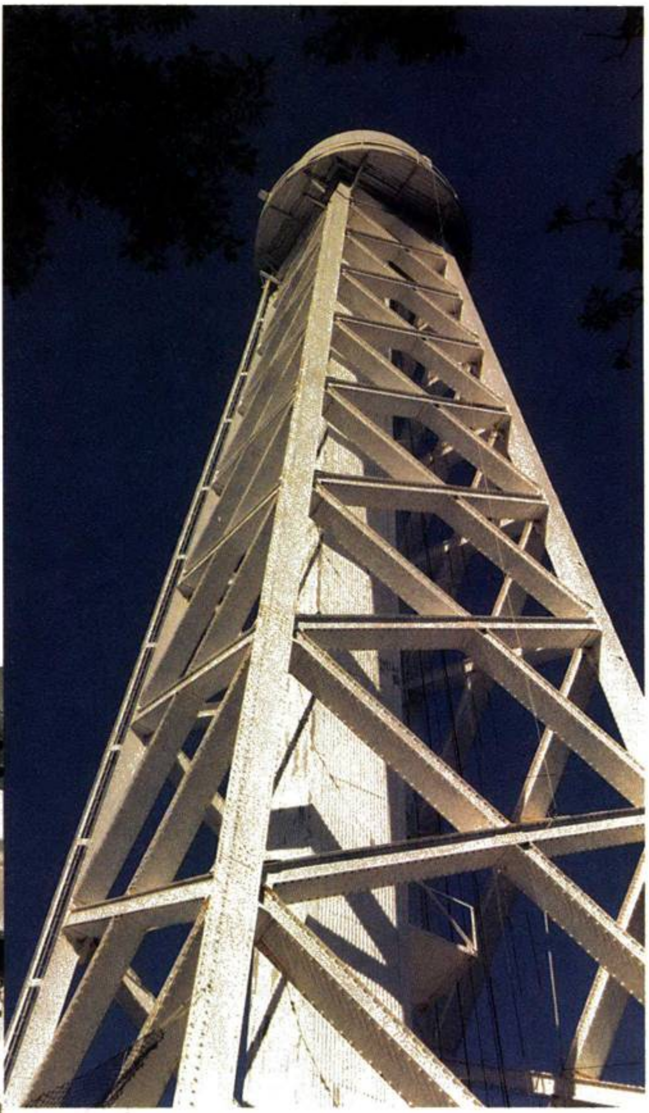
Mount Wilson: A Versatile Observatory

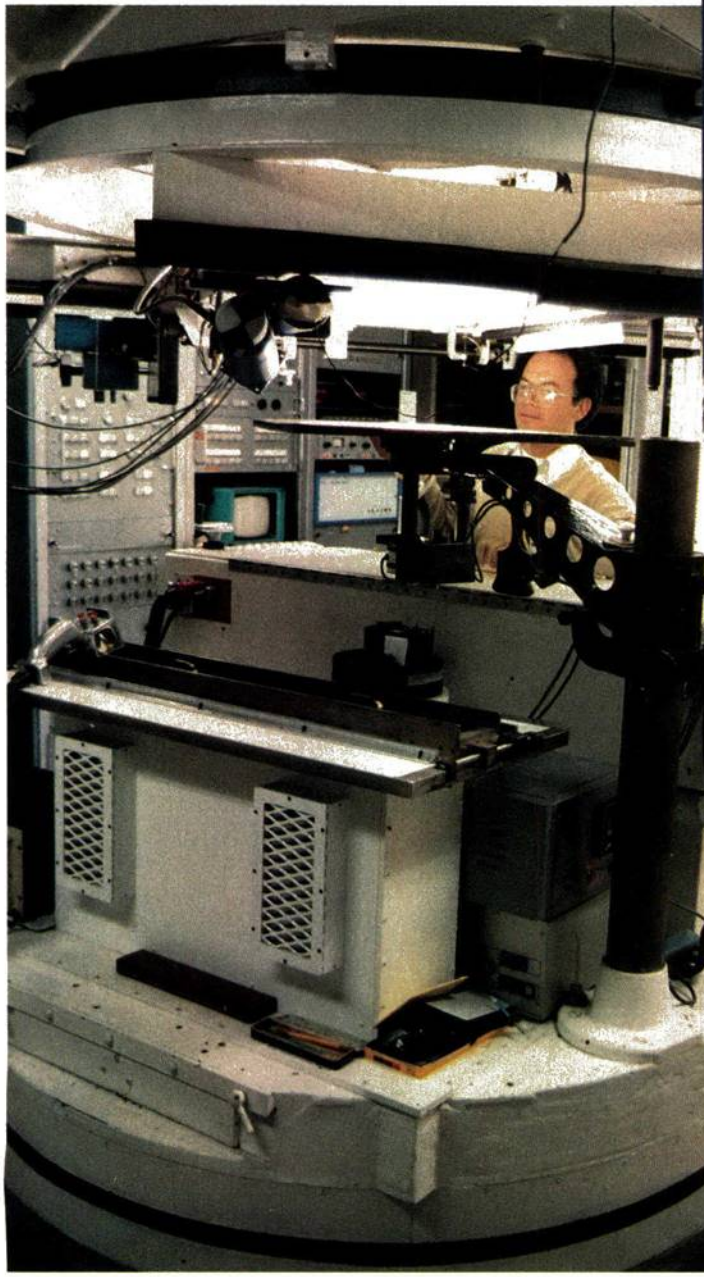
Right: A 150-foot-tall tower raises the optics of this solar telescope far above air turbulence and heat from the ground.

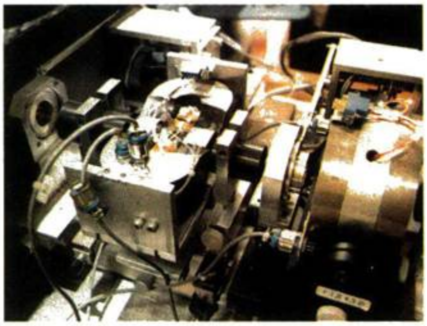
Below: At the focus of the tower, observer Steve Padilla checks that the 18-inch-diameter solar image is properly centered. From here, sunlight enters an 80-foot spectrograph that makes a map of the Sun's magnetic fields every 12 minutes.

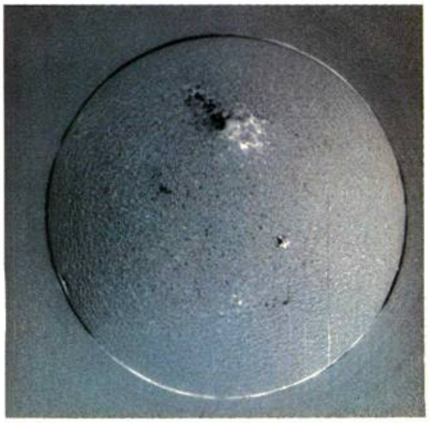
Lower right: Dedicated to measuring the oscillations of the Sun's surface to deduce the Sun's interior structure, state-of-the-art instrumentation in the 60-foot tower produces high-resolution CCD images of the Sun in a very narrow band of wavelengths. After computer processing, the instrument reveals motions of a few meters per second and magnetic fields (circular image) on the Sun's surface.

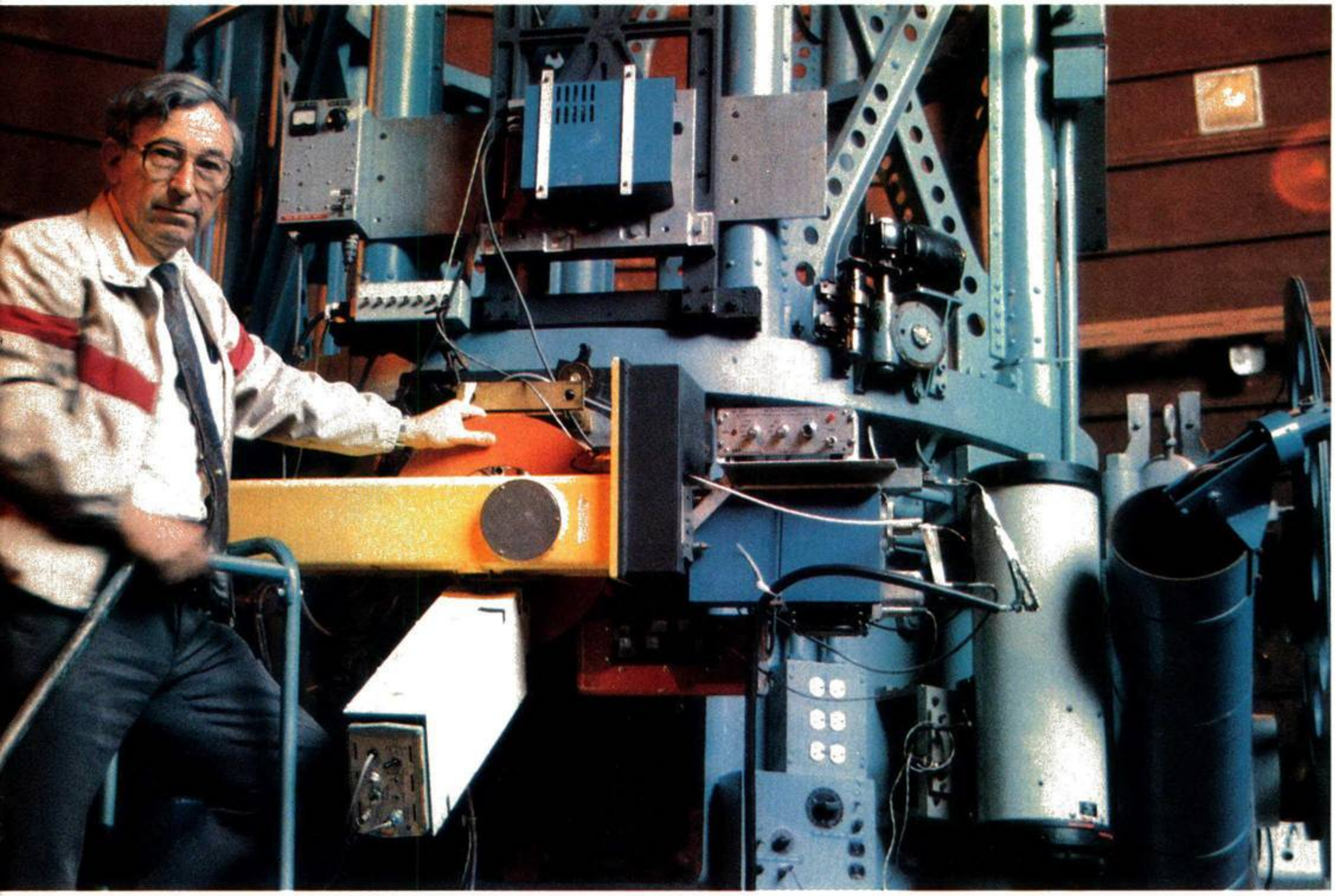
Opposite page: Do distant stars have sunspot cycles like the Sun? The "H-K" spectrometer mounted on the 60-inch Mount Wilson telescope measures the total magnetic activity of Sun-like stars every clear night. Because sunspot cycles are likely to be as long or longer than the solar cycle — 22 years — observations must span decades.











willingness to turn the observatory's buildings, equipment, and property over to the Institute, pending certain conditions.

Carnegie wanted to be sure Mount Wilson Observatory would be run in a responsible manner. It needed assurance that the new operator would recognize prior agreements with UCLA, USC, and Harvard — and that these would be honored.

The Mount Wilson Institute

"With an organization starting from absolute scratch, we need a board that includes all of the various elements," explained Bob Ferguson. "The Organizational Board of Trustees consists of Art Vaughan and myself; Bob Nelson, who's a retired vice president of the Times-Mirror Company; Ed Rhodes and Roger Ulrich, who operate the two solar observatories; Craig Black and Ralph Cryder from the Museum of Natural History and the County of Los Angeles Department of Parks and Receation, respectively; and Ray Weymann of the Carnegie Institution on an *ex officio* basis. Our job is to set up the institute and get the ball rolling."

Arthur Vaughan is chairman of the Mount Wilson Institute's Organizational Board of Trustees and an astronomer at the Jet Propulsion Laboratory in Pasadena, California. He has designed spacecraft optical systems, the wide-field planetary camera for the Hubble Space Telescope, and the H-K spectrometer, the powerful instrument used on the 60-inch telescope for measuring stellar activity. C. Robert Ferguson, the treasurer of the Mount Wilson Institute, is a Pasadena attorney and the director of Stony Ridge Observatory, an observatory near Los Angeles designed and built by amateur astronomers.

Once the Organizational Board of Trustees has set up the Mount Wilson Institute, Vaughan and Ferguson explained, it will turn the operation of the observatory over to a permanent board of trustees.

In the Public Interest

The Mount Wilson Institute intends to focus public attention on Mount Wilson through links with a variety of local educational institutions and businesses.

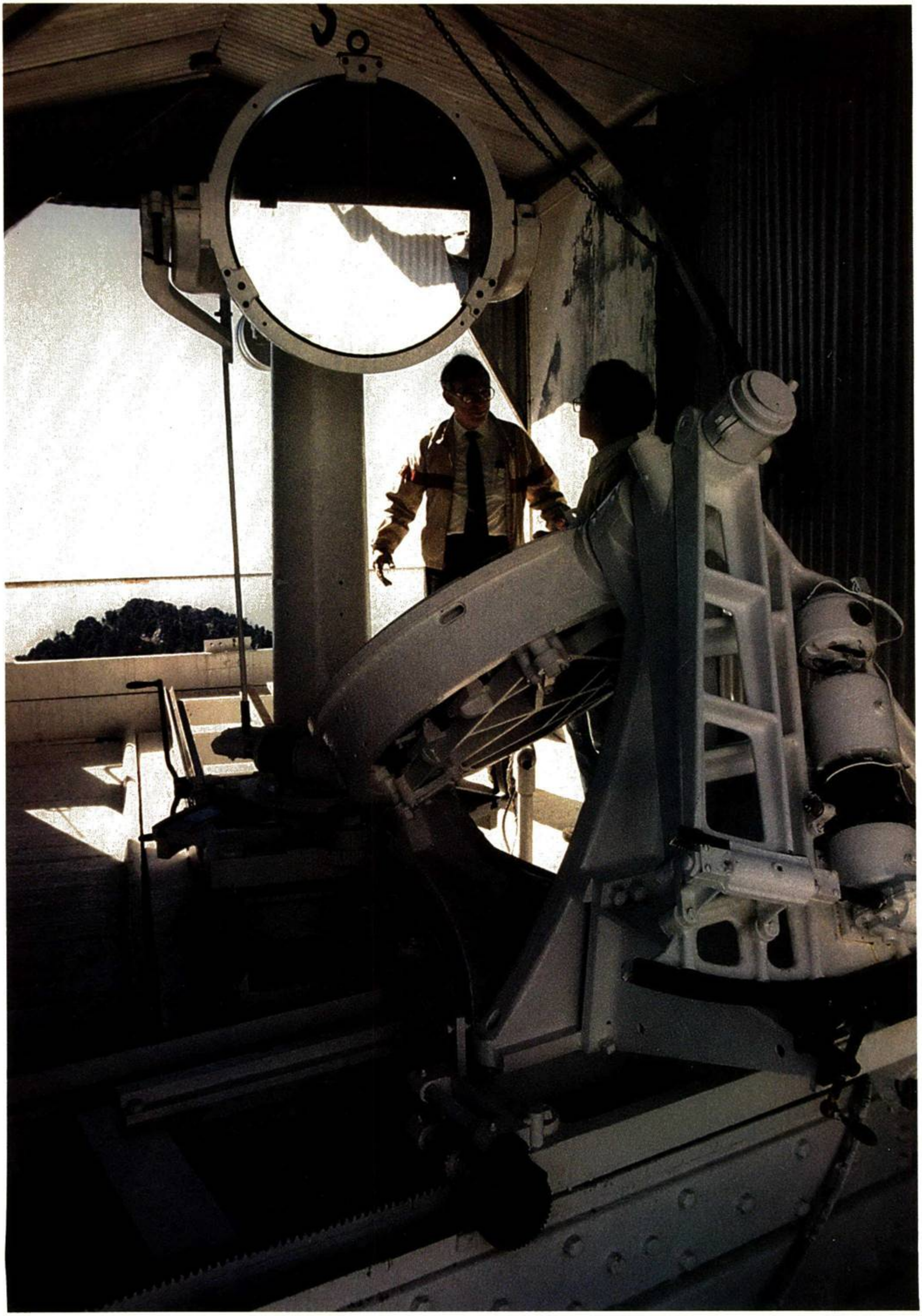
"Let me give you an example," said Vaughan. "Ralph Cryder of the parks department envisions involving the Los Angeles city school district and the local San Gabriel school district. The school districts will bring day tours up here on a regular basis, which will intensely involve the school districts with lectures and talks.

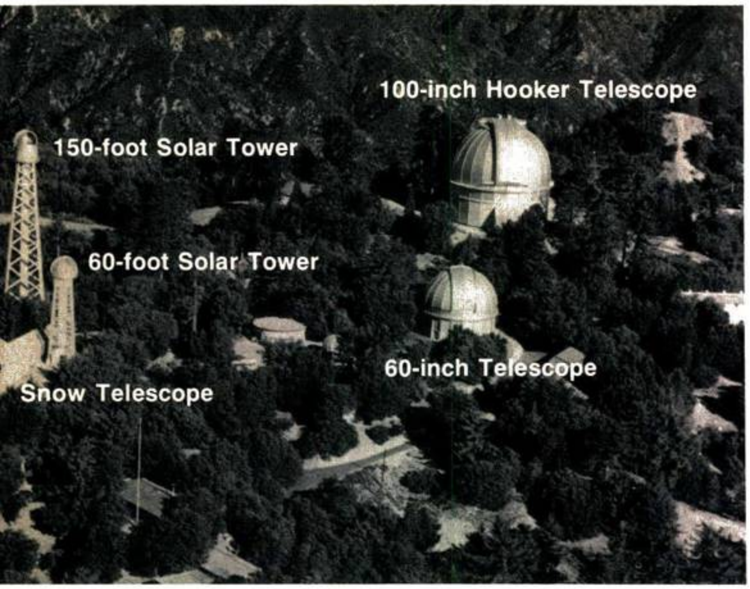
"The Museum of Natural History will have museum staff develop exhibits both up here and downtown. We will cooperate with the museum people as enthusiastically and fully as possible to make those developments."

One possibility is beaming live, real-time television images to the small museum located on the observatory grounds and to the Museum of Natural History via microwave link. During the day this would be a high-resolution solar image; at night it might include low-light-level television from one of the telescopes.

Another link with the public is the Mount Wilson Observatory Association, a volunteer group that runs a docent program for tourists, keeps up the museum, and publicizes Mount Wilson.

"There's going to be a lot more amateur astronomer involvement," said Ferguson. "It's ironic: the amateur astronomers at Stony Ridge Observatory thought, why not convert the 100-inch into an amateur telescope? Obvi-





Above: Mount Wilson's telescopes nestle among the trees on a ridge high above Pasadena, California. With a new operator and funds raised from the general public, the observatory will remain scientifically productive into the twenty-first century. Photo courtesy of the Carnegie Institution of Washington.

Opposite page: Massive mirrors once beamed sunlight into George Ellery Hale's horizontal Snow solar telescope, the first research instrument built on Mount Wilson. Long since replaced by the tower telescopes for research, the instrument is nonetheless still used to train undergraduate students from UCLA.

ously that's not going to happen, but it shows there's a lot of interest in expanding the amateur involvement at Mount Wilson."

The Pulse of the Sun and Stars

George Ellery Hale founded Mount Wilson Observatory to do solar astronomy. Beginning with a huge horizontal solar telescope (named the "Snow telescope" after its donor, Helen Snow), Hale built first a 60-foot-high tower telescope and then a tower 150 feet tall, still the largest instrument devoted to continuous solar study.

The 150-foot tower operates every clear day, all day, making magnetic maps of the Sun's surface. "We get twenty to twenty-five fast magnetograms a day," explained observer Steve Padilla. The accumulated database of solar observations from the tower, invaluable for studying the 11-year cycles of sunspots and 22-year cycles of magnetic activity, is unmatched anywhere in the world.

"They've installed roughly a million dollars worth of computer equipment in here in the last five years," said Vaughan, gesturing around the observing room of the 60-foot tower. Graduate student Steve Tomczyk explained the CCD cameras: "With this equipment we can measure motions over the whole surface of the Sun with an accuracy of about 10 meters per second per pixel in a 5-second integration. We get a lot of data. Every day that we run the experiment we fill a whole carton of 2,000-foot tape reels."

What the cameras watch are pulsations in the solar photosphere. Our star shakes and shimmies with a base period of 5 minutes. By comparing how the surface really moves against computer models of a shaking Sun, the astronomers can probe the interior structure of our star.

"We can see the rotation of the Sun and its differential rotation. We see large-scale convection near the surface and deep 'flows' occurring throughout the Sun," said Tomczyk.

After dark a different crew of astronomers starts work, this time on the 60-inch telescope, monitoring Sunlike stars for starspot activity. The "solar-stellar connection" is a long-term program. Since 1977 it has used the 60-inch telescope; before that it ran for eleven years on the 100-inch. From this program has come the discovery that the Sun is not alone: other stars do indeed have solar cycles.

Putting the 100-inch Back to Work

The 100-inch telescope offers the astronomers three unique features: the excellent seeing on the mountain, the excellent optical quality of the telescope, and the Mount Wilson Observatory's commitment to long-term and concentrated studies.

"The seeing here is superb," said Vaughan. "It's as good as the seeing on Mauna Kea on Hawaii. That means the site is perfect for people who are interested in high-resolution imaging with speckle interferometers or other adaptive optics. There are some groups ready to undertake this kind of work with the 100-inch as soon as the telescope is available."

Light pollution does not matter in the type of work the Mount Wilson Observatory plans to do. For solar astronomy it does not matter at all. Ultrahigh-resolution imaging and studies of stellar spectra are quite insensitive to the effects of light pollution.

"One area I'm particularly interested in," said Vaughan, "is using the 100-inch to extend our studies of solar oscillations to stars. By developing very sensitive instrumentation, we should be able to detect the stellar analog of the solar 5-minute oscillation. In stars that are much more active than the Sun, the oscillations might be much more strongly excited. Who knows what we'll find?"

The instruments Vaughan envisions would be capable of measuring exquisitely tiny variations in radial velocity and able to detect small oscillations of only a few meters per second. "These oscillations tell us about the Sun's interior," Vaughan explained. "They open the door to probing the interiors of the stars." The astronomers also hope to pick up exceedingly small variations in radial velocity that result from the gravitational perturbations of planets.

Seeking Support

The Mount Wilson Institute is seeking an endowment of $10 million in the next five years to provide sufficient income for the annual operating costs of $600,000. Since October the institute has received voluntary donations totaling over $8,000 and it is now using these funds to seek major grants from local foundations. The institute also welcomes grants, donations, and gifts from individuals and corporations. This money will allow the institute to operate and upgrade the observatory. To support scientific research, federal funding will be sought.

"The primary purpose of this mountain is to conduct astronomy," said Ferguson. "Everybody understands that. And everybody understands that the astronomy we do up here is done on objects brighter than 19th magnitude. Everything else — the museum, the parks, the student involvement, the public recreation — revolves around the astronomy and is here because the astronomy is here."

The Mount Wilson Institute is currently seeking $2 million to meet its goal of operating and upgrading the Mount Wilson Observatory. Those wishing to become sponsors may write to: The Mount Wilson Institute, 301 East Colorado Boulevard, Suite 600, Pasadena, CA 91101. Contributions are tax-exempt.

ASTRONOMY Forum

Space Writer Robert M. Powers: Dreaming of Mankind's Life on Mars

Robert M. Powers has been writing about science and space for over twenty-five years. In his most recent book Mars: Our Future on the Red Planet *(Houghton Mifflin, 1986) Powers explores mankind's dream of exploring and eventually living on Mars. He describes the past exploration of Mars as well as what manned trips to the planet would entail. Powers not only examines practical ways to colonize and terraform the inhospitable surface of the planet but impractical ways to go about it too.*

Powers has covered the Viking *landings on Mars at the Jet Propulsion Laboratory as well as launches from Kennedy Space Center. His previous books include* Planetary Encounters *(Stackpole Books, 1978),* Shuttle *(Stackpole Books, 1979), and* The Coattails of God *(Warner Books, 1982), which earned Best Book awards from the Aviation Space Writers Association. He's currently working on a novel. Powers divides his time between residences in Boulder, Colorado, and Tucson, Arizona.*

ASTRONOMY: In *Mars: Our Future on the Red Planet* you state that your purpose is to show your readers how to "fall in love" with Mars. Why?

Powers: Why we should fall in love with Mars is all part of a human dream. Our ability to dream is what separates us from all the other species on this planet. Martin Luther King, Jr., for example, had a certain kind of dream. Other people have been dreaming of human health and welfare for centuries. We now have a lot of health, thanks to people with a medical dream.

We who believe in space travel and space exploration also have a dream, and it is the product of just about as many centuries as some other human dreams. I think the space dream is just about as strong too. And Mars is an attractive talisman for that particular human dream.

ASTRONOMY: Why is Mars a more attractive talisman for that dream than colonizing our own Moon, for instance?

Powers: Because Mars holds out the possibility of life.

Nearly four hundred years ago Giordano Bruno was burned at the stake for heresy, and among the heresies he was responsible for was the notion that there are other worlds than Earth and that those worlds might be inhabited. If he'd said that today, he'd get on the Johnny Carson show, but back then that was an extremely dangerous idea. It went counter to all of civilization's thinking at the time.

Well, we're not alone. There are other people, other places, and we need to find them, to see them, to find out what they know about creation. Oddly enough, in the eighteenth century this speculation about other people, other planets, other places, was a part of ordinary parlor conversation. But in the eighteenth century science started to become very technological, and we have since learned that the other planets in our solar system are not as interesting as Mars, are not much like the Earth, and so on.

Mars always held out hope for life because it had polar caps. It had what looked like seas and continents. We knew it had an atmosphere. All of this boiled down to the wonderful human idea that there might be somebody else there, and it came to a head in the late nineteenth century with Percival Lowell, who established an observatory in Arizona.

ASTRONOMY: And we all know what he found.

Powers: Yes, we all know what he found: canals. He and Bruno essentially invented the Martians. The concept is still that we are not alone. What is a Martian, but someone from another civilization? It all came down to Mars, and there lies our fascination.

In the newspaper recently I read we're still talking about life on Mars. There's an argument raging right now, ten years after the *Viking* landings, about whether we've found microbiotic life. We still want to find life somewhere else.

ASTRONOMY: The best evidence of life from the *Viking* probes seems to indicate that "either there is or isn't life." Seems as if you might as well flip a coin.

Powers: That's true. The soil of Mars has somewhat bizarre qualities. If you take the positive view, then those qualities exhibit a performance that would indicate some sort of organic material in the soil. If you want to take the negative view, you'd say, "Yes, but I can duplicate those same things with chemicals." It's unfair to say you have found life as long as you can duplicate it by chemical means. You can take either side of that one.

ASTRONOMY: What will it take then? A close-up shot of a Martian's foot about to crush the *Viking* camera

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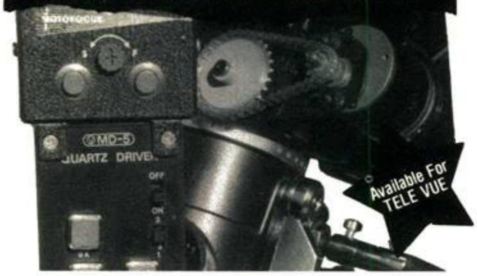

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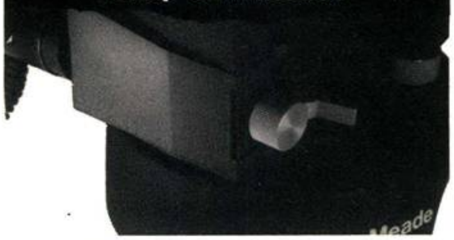

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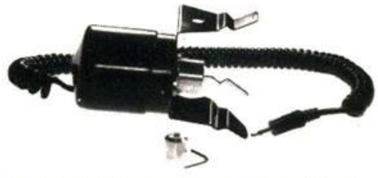

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Powers: I think a manned landing or more robot landings can ultimately solve the question of whether there's life on Mars or not. By life, of course, we're generally talking about molecular chains, "tending in the direction of life," as the biologists say. We're talking about organic molecules; we're not talking about life in the sense of any highly developed species. Martian microbes would be about the best we could hope for.

My view is that it is highly unlikely Mars has any form of life other than that defined as organic-type chains. But that doesn't mean life can't exist on Mars, because we can be the Martians. That's a bit of the point I tried to make in my book: We've had this grand dream of Mars and Martians, cities and canals, and with spacecraft we found that Mars is not really like that. There are no canals, in the sense Lowell thought of canals. There are no cities, as Bradbury wrote about so elegantly. No rivers of lavender wine in the canals.

But we can live on Mars. It is a planet very much like the Earth in geological terms. Even though we regard Mars as a planet with a bad atmosphere from our viewpoint right now, that it's rather cold, Mars is not the dead and desolate Moon by any stretch of the imagination.

One of the wonderful things that happened during the *Viking* missions was that we got surface pictures of Mars and they looked as if it were wintertime. There was frost over the landscape; frost came down over the lander. It looked like the Arizona Sonora desert without the cactus.

What's so fascinating, for those who are fascinated by going to Mars, is that it is not like going to the Moon. Mars has water in the form of permafrost. It's much like the Alaskan tundra: there is a lot of water in the soil bound up some inches down. There is also a considerable amount of oxygen, because the soil with its bizarre properties can be heated, and when you heat it, it creates oxygen!

So if we go to Mars, we can actually get the oxygen required to stay there simply by chucking Martian soil into a little solar cooker and extracting the oxygen. It is not a complicated technology. Water is also available there.

But traveling to Mars is certainly not the same thing as the Greenlanders coming over to the North American continent in the year 1000, because Mars is not like Earth. But it is hardly the Moon either: it's not like going into airless space. It has its own resources.

ASTRONOMY: Are you talking about an enclosed, air-filled area, where if you need some air you just go outside and dig up some of the backyard, or are you talking about planetwide terraforming?

Powers: I think the first explorations will unquestionably be a little lunarlike. We'll have to wear space suits, for instance.

However, one of the interesting things we have discovered using spacecraft — not only *Viking* on Mars but the Russian experiments on Venus — is that the Earth is like a cosmic baby bear's porridge: Earth just happens to be in the right place at the right time, and it's "just right." Venus is too hot to support life; Mars is a little too cold to support life.

Mars is currently, for want of a better word, in an ice age. That immediately leads us to wonder what would happen if Mars were to warm up a little bit. What if we were to artificially alter its ice age? Now these things can come around in natural ways. For instance, there has been some scientific concern that the Earth is warming up. Earth may be slightly warmer in the next century than it is now. This causes a lot of worry, because if our polar caps melted, we would inundate some of our famous and rather useful coastal cities. However, if the same thing happened on Mars, we would simply get more water on Mars, the atmospheric pressure would rise, and we would have running water again where it's frozen now. The planet would assume a slightly different evolutionary track than it's on now. It would become more Earthlike.

ASTRONOMY: The Soviet Union, in addition to its unmanned *Phobos* mission to Mars this summer, is considering a manned mission. How far away is the possibility of manned missions to Mars?

Powers: If the United State decided today to land a manned expedition on Mars, we could see it in the very earliest years of the next century. We could even do it before then in some respects, but it would simply take that long to get some of the technology together. You have to remember that in 1969 NASA had a Mars mission planned. It used the same kind of equipment that landed on the Moon. We could have landed two men on Mars and had one guy circling overhead just as we did on the Moon.

There is nothing in the technology that we can't produce, but we do need the lead time. We need a decision. We need a presidential administration that says, "Hey! We're a space power here! We're looking at the twenty-first century! We're going to go for it!"

ASTRONOMY: What effect will the *Challenger* tragedy have, if any, on our exploration of the planets?

Powers: I don't think in the long run it's going to have much of an effect.

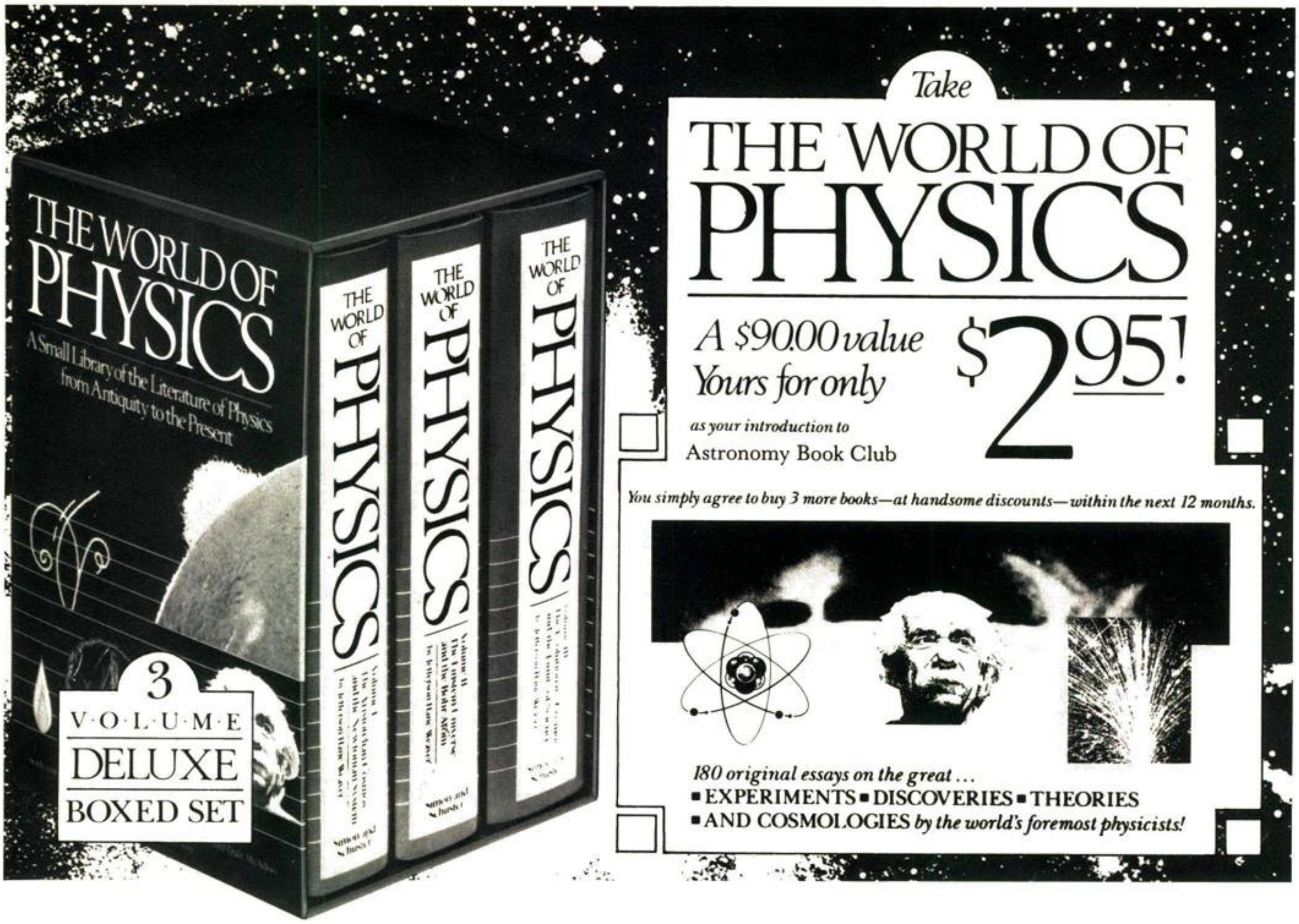
An Excerpt from Robert M. Powers' *Mars: Our Future on the Red Planet*

Who owns the Martian base may one day become a thorny question. The Outer Space Treaty of 1967 clearly says that the spacecraft and "objects landed or constructed" on a planet are owned by the nation that launches the expedition. This seems clear enough, but it really isn't. A space lawyer might point out that this only implies things constructed from Earth materials. The treaty says nothing about objects built of native materials.

It does appear, however, from the few legal precedents available, that no one will own Mars. The treaty, always providing it is observed, denies the territorial claims of anyone to a celestial body. This is why the United States does not own the moon by right of exploration, as would have been the case had the treaty not been signed two years before the *Apollo 11* lunar mission. The ancient privileges of exploration do not apply to the solar system. Whether that will remain the case is somewhat doubtful, considering history. . . .

Whether the Moon Treaty or some later version of the same thing is ever ratified by a majority of nations — only the United States and the Soviet Union have much chance of establishing permanent bases on either Mars or the moon in the foreseeable future — the politics and legal battling may only begin with trying to decide if [anyone] born on Mars is a Martian.

If the colony on Mars becomes large enough, and there is every reason to think that it will, there will eventually be a movement to free Mars from the tentacles of mother Earth. Since we seem condemned to repeat the mistakes and misfortunes of history, perhaps it will come to war: the real "war of the worlds." Who knows? Maybe H. G. Wells was more prophetic than we thought. Martian spaceships may one day descend on Earth to battle the inhabitants. Only the Martians will be ourselves.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Partly because the long lead time required to design any kind of a mission, including an unmanned one, is such that the people who work on those missions are working on them now. For example, no one has stopped working on the *Galileo* space probe to Jupiter because of the current hiatus in launch ability. The mission has to be completed and ready to launch, regardless. Also, people who are working on the manned space station design and various life support systems and things like that have not stopped working either.

I think in the long run we're going to have a very needed hiatus in the space program in the sense that we need to re-evaluate some things. I think those will be re-evaluated and we'll come back much stronger.

ASTRONOMY: Will we come back not only stronger but with better equipment? Better hardware?

Powers: I think so. And it's very important for the public to realize that we are not dealing with the world of science fiction or the world of space buffs. We have to remember that about twenty-five years ago the sum total of the world's investment in artificial satellites was a few hundred thousand dollars. I would hate to guess what the world's investment in satellites is now!

If we were standing at Kitty Hawk and saw the Wright brothers' little airplane go flopping over the sands, and I turned around to someone and said, "Seventy-five years from now the world's investment in airplanes will be 20 percent of the world's economy," that person would have just looked at me and put me away.

If we don't realize that the twenty-first century will be the world of space — economically, militarily, and in an exploration sense too — we're really not looking at the lessons of history, because clearly that's what is going to happen.

A. J. Austin
Manchester, Connecticut

Stargazing from 35,000 Feet

The grey skies were darkening as I pulled into the employees' parking lot of the airport. I met Captain Barr in the dispatch office; I had flown as his first officer many times before. As he and I reviewed the paperwork for the night's Newark to San Francisco trip, it became obvious that, except for the Northeast, the weather across the nation was beautiful. This was good news for both of us but for different reasons. For the captain it meant fewer headaches; for me it meant more stars.

As I stuffed the paperwork into an envelope, I remarked to the captain that we had been blessed not only with good weather but with a moonless night as well. He looked at me blankly. I could almost see his mind trying to compute what I had said. "Oh yeah, I almost forgot," he said, "I'm flying with the 'Starman' tonight."

We made our way through the maze of corridors and out to where our aircraft was parked. It was raining. The four Pratt and Whitneys growled like lions and the rain hissed on the windshield as we leaped upward through the layers of cloud. Then, finally, at 18,000 feet the plane topped the inclement weather and we took our first look at the night sky. The view was not spectacular, though, because the evening was still too young. We leveled off at 35,000 feet and eventually resigned ourselves to the hours of tedium ahead.

At 35,000 feet your view of the heavens can be obstructed by the same vexations you face at sea level. A thin veil of high cirrus clouds or a brightly lit Moon can easily ruin the celestial scenery. The numerous patches of city lights passing below can pollute the sky and kill the starlight even at this altitude. During nights like those it is best to wave the white flag and retreat to the job at hand.

If a very bright star or planet is situated close to the horizon, the atmosphere will bend the object's light waves in much the same way it does at sea level. The most striking example of this is Venus. When Venus nears the eastern or western horizon, its light refracts and appears to cycle through all the colors of the spectrum. At times the colors are so brilliant that many airplane pilots will flash their landing lights at this planet, mistaking it for another plane. On occasion I have been obliged by skeptical crew members to produce a current issue of ASTRONOMY to prove the identity of the unidentifiable object.

There are nights, however, like tonight, when the air is clear, the Moon is gone, and the city lights are far behind. The sky opens its doors to reveal a magnificent celestial panorama. Individual stars burn with unwavering clarity. Their colors are pure and obvious even to the untrained eye. A casual observer can easily disassociate the brighter stars from background stars, connect them with an imaginary line, and scribe their passage from horizon to horizon. The Milky Way glows with a startling incandescence. With the unaided eye, you can identify the larger nebulae and star clusters in the denser regions of the Milky Way.

Elusive phenomena like the zodiacal light or the northern lights occur often and more dramatically than at sea level. The impact of such phenomenon is heightened because at 35,000 feet you have an unobstructed view of the entire phenomenon. At a glance you can see the whole area of zodiacal or northern light unobstructed by trees, buildings, or mountains.

I don't know if Einstein ever flew in a jet aircraft, but if he had, he would most certainly have noticed how speed can alter your perception of time and space. The night can be longer or shorter depending on whether you're flying eastbound or westbound. Likewise, the life of a sunset or sunrise can be abbreviated or extended. The Sun can be made to rise or set over any horizon depending upon the direction of flight.

As we winged our way westward, the skies grew darker and darker. I consulted our internal navigation system computers and tracked our progress on an airway chart. We were in the vicinity of Pawnee City, Nebraska — the nation's heartland. By this time the few remaining lights burning far below were being extinguished by the weary farmers of America. Darkness fell upon the land. Five minutes and forty miles later the Earth's blackness bled completely into the moonless void above. I leaned forward in my seat to get a better view.

I pressed my nose against the thick pane of heated Plexiglas before me. My eyes beheld a sharply focused panorama of the cold Nebraska night sky. To the north the ever-present circumpolars pinwheeled about their private corner of the heavens. Ursa Major looked like a reclining plow, abandoned on the northern horizon. Directly ahead was Cygnus the Swan, stuck like a dagger in the western horizon. To the west-south-west Jupiter and Mars, like us, appeared to be heading towards the west coast. Farther south I could identify Cetus the Whale immortally splashing about in its sea of dim stars. Although I could not see behind us, I imagined the belt of Orion poking above the eastern horizon, marking the coming of winter.

I dimmed my instrument lights, hoping to eliminate the glare from the windshield before me. This caught the captain's attention. "It looks like Starman's at it again," he said to our flight engineer. As if on cue a meteor fell far off in the distance, consuming itself in a brief flash.

"Yeah," I said with a grin, "Starman's at it again."

Steven A. Oetzell
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ASTRONOMY

In Focus

Enhanced Astronomical Notebooks

Sir / I have been waiting to see an article like "Should You Keep an Astronomical Notebook?" by Andrew M. Thorpe (Equipment Atlas, January 1988) for the ten years astronomy has been my hobby.

The notebook I've kept includes codes for day, time, atmospheric conditions, and instruments used. In general I record my best description of an object's position and size relative to nearby stars and objects, which has helped me to memorize the shape and position of many objects. In addition to describing my emotions and thoughts on what I am seeing, I also list any guests I have, events, and observatories I visit.

I have dabbled at drawing though mostly just to show where an object is. For example, I have recorded 61 Cygni's position so I can draw it again in a few decades to see how the star has moved. I also use a pocket tape recorder and then write down what I've seen later when I'm inside where it's bright and warm.

The human memory is astounding, but it is not flawless, so my notebooks are my most valuable possessions — irreplaceable and often fun to read and read again.

Karl W. Bornhoeft
Seattle, Washington

Sir / I agree with Andrew M. Thorpe that maintaining a record of your observations is an invaluable resource to serious amateur astronomers. But I also feel that taking notes while at the telescope is difficult at best and that the alternative, which is trying to remember the details of a two-hour observing session once you have gone back inside, is hopeless.

A solution I have found for these difficulties is a miniature tape recorder with a voice-activated microphone attached to the telescope tube with strips of Velcro. I can dictate while observing and immediately enter the taped observations into my computer when I finish an observing session.

I put my notes into a database management program customized for astronomical use. Because the program allows me to retrieve data on the basis of various specified criteria, before an observing session I can search the program to determine which objects or types of objects I have observed in a particular constellation. I can also compare the detail visible under different weather conditions, time of year, or with various telescopes. Any diagrams I may have drawn are cross-referenced from the computer data to my scrapbook.

Francis R. Stark
Montreal, Quebec, Canada

We're Not Alone

Sir / "The Primal Fear: Are We Alone?" by Frank Apsi-Ridolfo (Forum, December 1987) was an eerie, philosophical article that really depressed me. Mr. Apsi-Ridolfo has the notion that he can speak for all of humanity when he wrote, "Human beings obviously have a strong need to find life apart from what has evolved on our planet."

There are some 5 billion other people on Earth, and I don't feel the need to contact a group of extraterrestrials on some distant world to quench my utter loneliness. However, I do understand the hopelessness an astronomer must feel when he peers into the vast but inexplicably beautiful cosmos if he believes man is nothing but an insignificant organic blob without reason or future.

I prefer the theory that says we, along with the rest of the universe, were created for a purpose.

Leif E. Pierson
Farmers Branch, Texas

Great Orion's Nebula

Sir / Your four-page article, "Orion's Great Nebula" by David J. Eicher (The Backyard Astronomer, January 1988), was excellent. Orion has long been my favorite constellation and the article points out some of the intrinsic beauty in "the nearest dark sky."

Clayton Jones
Madisonville, Kentucky

Our Future in Space

Sir / Many people think that, just because the Soviet space program is ahead of ours, the United States is failing in its exploration of space. I disagree with that view. Space exploration is *not* a competition: it's an effort to find out facts about the things we dream about.

If the United States can't work with the Soviets, then the United States should just concentrate on itself. We shouldn't rush to catch up to people who are trying to get ahead of us.

Kathy Anderson
Indialantic, Florida

Sir / One concern of Martin Sickler in "Winning the Battle of the Space Budget" (Forum, August 1987) is obtaining widespread public support for near-term exploration of the Earth and the solar system. Those of us who read ASTRONOMY probably do not need to be convinced of the importance of these issues. The problem is to propagate these ideas in a more commonly accessible medium.

I believe television can contribute to this purpose. A properly developed weekly television series would bring home the adventure, drama, and excitement of space exploration. Many television viewers would find a realistic depiction of the real and potential problems we will face in Earth orbit, on the Moon, and on Mars to be very stimulating.

A weekly series could also become

a forum where serious ideas and concerns of scientists and engineers are developed in the plots of the shows. Viewers could be encouraged to submit their own ideas in response. At the same time, strong character development, maintained throughout the series, would show the human side of space exploration and keep the interest of nontechnical viewers, whose support would be required to maintain series ratings.

We need public support to maintain long-term, meaningful space initiatives. Television can contribute to that goal.

Dave Wanamaker
Ottawa, Ontario, Canada

Understanding Spirals

Sir / "How Do Spiral Galaxies Spiral?" by Neil Comins and Laurence Marschall (December 1987) explains something that has fascinated me for years and illustrates something I discovered quite by accident.

Recently while brewing coffee at work, I found an amazing thing. We use a cheap instant coffee powder and this causes masses of minute bubbles on the surface of the mug. I always stir the coffee vigorously and that's how I made my discovery. The rapidly swirling bubbles on the surface of the freshly made coffee appeared astonishingly like a spiral galaxy. A large nucleus formed with spiral arms swirling and changing, disappearing, and reforming in what I fancy as a vastly speeded up view of galaxy formation. Now before you send the shrink over to analyze me, try it and see for yourself.

Of course, I make no claim to any scientific credibility for my discovery, but there are many instances of scientists not being able to see the wood for the trees. Could not the invisible dust in a large galaxy act like the liquid in a cup of coffee? They locked people up in the old days for saying the Earth was round, didn't they?

Derek A. King
Huntingdon, Cambs, England

Sir / I suggest you start explaining fancy words like "stochastic process" to us common folks ("How Do Spiral Galaxies Spiral?" by Neil Comins and Laurence Marschall, December 1987). I am sure some of this terminology is fairly new, and we amateurs just do not keep up with these four-bit words. I'm almost afraid to tackle the article.

Richard X. Melendez
Duarte, California

— The term "stochastic" was used in one of the article captions, but the term was defined in the article as any random process.

Sharing Our Universe

Sir / In Behind the Scenes (October 1987) Richard Berry touched on one of the most important contributions an amateur astronomer can make to the hobby: sharing the starlight with others and helping them visualize the universe they live in. I have attended star parties where twenty telescopes were pointed at the Hercules Cluster, and I have found that few, if any of the observers knew where within our universe they were looking.

I would gladly share the information we have compiled that shows the positions of NGC objects in our Galaxy and outside it. This information could be used in programs that present the universe to the public.

Daniel Taylor
Northwest Sidewalk Astronomers
57500 Timber Road
Veronia, OR 97064

Chapel No Threat to Palomar Skies

Sir / I would like to present these facts to all concerned about light pollution on Palomar Mountain (In Focus, October 1987).

There will be no outdoor field lighting for the planned Calvary Chapel of Costa Mesa in southern California. We will preserve the dark sky. We purchased this land to enjoy the stars, and we are installing our own observatory.

The buildings nearest Palomar Observatory are 3.5, not 2 miles from the observatory, and we are approximately 400 to 500 feet *down* in Jeff Valley.

The project is planned to accommodate 679 guests and staff maximum during the summer only, because much of the facility will not be winterized.

We care about preserving the environment as much as astronomers do. Contact the San Diego County Board of Supervisors at 1600 Pacific Highway, San Diego, CA 92101, for a copy of the environmental impact report, which is available for public viewing.

Chuck Smith
Calvary Chapel of Costa Mesa
Santa Ana, California

Behind the Scenes

Let's Make Certain It's Dead

Mars is once again in the news. There's talk of exploring and colonizing this neighboring world.

Twelve years ago two *Viking* landers set down on the Martian surface. With extendable sample arms, the landers dug up clods of the Martian soil and dumped them into waiting experiments. We waited while the experiments ran, as highly reactive Martian soil made *Viking*'s "chicken soup" solutions bubble and fizz. The answer to the big is-there-life-on-Mars question was, "It's a long shot."

Most scientists took this to mean "no."

"No" is a convenient answer. "No" means we can proceed with manned missions to Mars secure in thinking that whatever stuff we happen to spread around the Martian surface when we go is okay.

But no one has *proved* Mars is a dead world. Yet once humans land on Mars, it won't be a dead world anymore. We'll bring our microorganisms with us and contaminate the planet. Then what?

If Mars really is dead, then it's no big deal.

But suppose against all odds Mars has some form of indigenous life. Suppose hardy organisms survived from an early era and still flourish in a few low, relatively moist environments near the equator. Suppose these living things are well enough hidden that a cursory check by a geology-oriented Mars rover doesn't find them.

On a contaminated planet, how will we ever know we've found *real* Martian organisms and not some obscure terrestrial bug — something that traveled to Mars on a spacecraft or on a human being? Wouldn't it be embarrassing to have contaminated the only available exobiology?

We cannot assume Mars is dead. We must explore the Red Planet as if we expect to find life. We must prove it is dead beyond any reasonable doubt.

Rovers and robot vehicles — sterilized to prevent contamination — should explore the planet before any human sets foot on the surface. We have the technology to explore Mars. We have the technology to prevent contamination. We have the technology to detect life if it's present. Let's use that technology.

Sincerely,

Richard Berry
Editor-in-Chief

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Meade's famous 10" **2120/LX3 MCOG** now on sale, for a limited time only, for:

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Shown: 2120/LX3 MCOG

Includes Hand Control Unit!

STANDARD FEATURES & FACTORY-SPECIFIED EQUIPMENT, 2120/LX3:

Complete f/10 telescope tube assembly (10" aperture, 2,500mm focal length), with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity (multi-layer over-coated) mirrors; ultra-smooth anti-backlash focus mechanism; large 8x50mm illuminated-reticle polar-alignment viewfinder; 1.25" visual back (eyepiece holder); 1.25" prism-type star diagonal, anti-reflection coated; Series 4000 Super Plossl eyepiece, 1.25"; rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; QUARTZ MICRO-ELECTRONIC SIDEREAL-RATE DRIVE SYSTEM and ultra-precision "LX" worm-drive gearing built into telescope drive base; POWER CONTROL PANEL (also built into drive base) WITH CONTROLS, INDICATORS and CONNECTORS for various accessory and auxiliary electronic equipment (includes input power connector; red LED indicator light; "Internal-External" drive control switch; brightness adjustment knob for *optional* illuminated-reticle guiding eyepiece; power jacks for: (1) the "Drive Control" hand-control unit ["Electronic Command Center"], (2) *optional* declination control motor, (3) *optional* LED map light, and (4) *optional* illuminated-reticle guiding eyepiece); ELECTRONIC COMMAND CENTER hand-control unit with: (a) "Quartz" (fixed) or "Manual" (variable) drive rate control switch, (b) variable (manual) drive-rate control knob (Lunar, Solar, Sidereal, etc.), (c) N-E-S-W drive correction control buttons, and coil-cord and plug for connection to telescope's Power Control Panel; AC power adapter with 25 ft. cord; 25 ft. DC power cord with automobile cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth (polar-alignment adjustments), latitude scale, bubble level and magnetic compass; ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; instruction manual; limited lifetime warranty.

2120/LX3 MCOG (List: $5,000) **$1,779.95**

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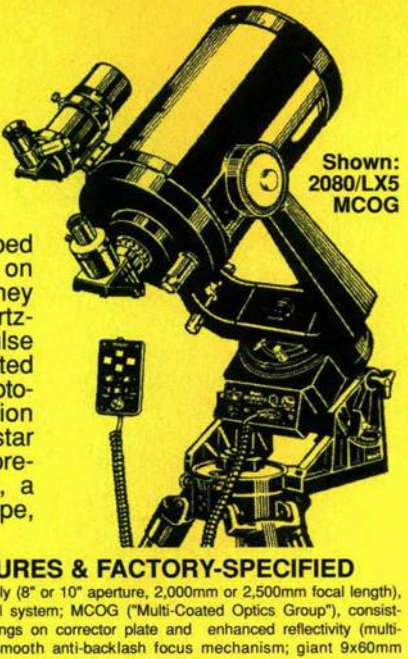

Shown: 2080/LX5 MCOG

The most fully-equipped Schmidt-Cassegrains on the market today! They come complete with quartz-lock microelectronic pulse motor drive, sophisticated hand control unit with photographic drive correction functions built-in, 2.00" star diagonal for advanced, premium-grade eyepieces, a giant 9x60mm finderscope, and much, much more!

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2080/LX5 MCOG (List: $3,600) **$1,689.95**

2120/LX5 MCOG (List: $5,200) **$1,959.95**

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Meade 2045 & 2045/LX3

Shown: Mod. 2045

Camera & T-Adapter for illustration purposes

Complete f/10 telescope tube assembly (4.0"A, 1,000mmF), with certified diffraction-limited optical system; high-transmission anti-reflection coatings on corrector plate; ultra-smooth anti-back-lash focus mechanism; 5x24mm coated achromatic finderscope; 1.25" prism-type star diagonal, coated; two 1.25" coated eyepieces (40x & 111x); rugged dual-fork astro mount, with frequency-controlled electric tracking motor built into base; graduated setting circles, manual positioning controls & clutches on both axes of motion; tabletop tripod legs (adjustable for latitude); dust covers; power cord; foam-lined metal-clad carrying case; instructions; limited lifetime warranty. **LX3 version has, in addition,** multi-coated corrector plate; LX3 QUARTZ MICRO-ELECTRONIC SIDEREAL RATE DRIVE SYSTEM, POWER CONTROL PANEL & DUAL DRIVE MOTORS, all built into drive base.

This unit can readily double as a high-quality terrestrial spotting scope or telephoto camera lens, making it an extremely versatile instrument. Many useful accessories and attachments are available for it.

2045 HTC (List: $1,300) .... **CALL**

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LensShade-DewShield, Mod. 712, for 2080	(List: $ 90.00)	**$ 62.95**
LensShade-DewShield, Mod. 710, for 2120	(List: $ 140.00)	**$ 97.95**
Accessory Tray-Shelf for Field Tripod, for 2080 or 2120	(List: $ 40.00)	**$ 29.95**
PIGGYBACK Bracket for camera, for 2080	(List: $ 50.00)	**$ 36.95**
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T-Ring for 35mm SLR camera (specify make)	(List: $ varies)	**$ 12.95**
T-Adapter for camera, Mod. 62, for all	(List: $ 50.00)	**$ 36.95**
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Off-Axis Photographic Guider System, complete, for all	(List: $ 250.00)	**$174.95**
Tube Balance Weight System, Mod. 1401, for 2080	(List: $ 130.00)	**$ 90.95**
Tube Balance Weight System, Mod. 1402, for 2120	(List: $ 140.00)	**$ 97.95**

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NOW SALE PRICED!

PwrStr-C8 II .... (List: $3,000) $1,589.95

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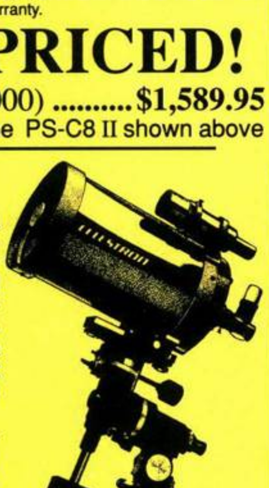
Super Polaris C8



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Complete f/10 telescope tube assembly (8" aperture, 2000mm focal length), with Celestron's world-famous, hand corrected, diffraction-limited, laser tested optical system; 6x30mm straight-thru finderscope; 1.25" visual accessory holder; 1.25" star diagonal; 26mm (77x), 1.25" barrel, multi-coated, premium-grade Plossl eyepiece; piggyback camera bracket; hand strap for holding telescope tube assembly during setup/takedown; quick-mount slider bracket for mounting and balancing scope tube; German-type equatorial mount with: (1) full 360° worm-drive slow-motion/manual-positioning controls on both axes, (2) setting circles on both axes, (3) vernier brake/clutches on both axes, (4) micrometer latitude adjuster (0-90°!) with latitude scale, (5) micrometer azimuth adjuster, (6) bubble level, (7) built-in illuminated-reticle polar alignment telescope, (8) sliding-type counterweight on quick-disconnect counterweight shaft, and (9) vibration-damping adjustable wooden tripod with accessory tray; foam-lined carrying case for telescope tube assembly; dust covers; instruction manual; limited lifetime warranty.

NOW SALE PRICED!

SP-C8 .... (List: $1,620) .... $ 929.95
SP-C8 StrBrt .... (List: $1,800) $1,039.95

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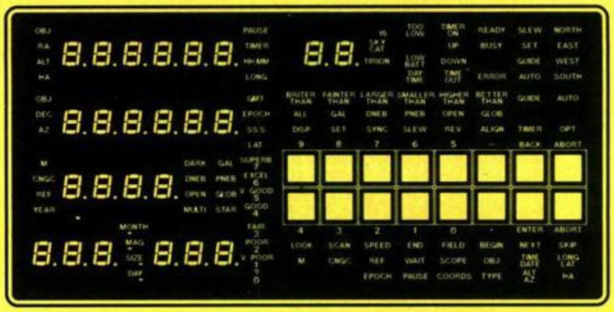
CELESTRON CompuStar



Celestron's *CompuStar* computer-controlled telescopes are the most awesomely powerful instruments available to the amateur astronomer today. With coordinates and data for nearly 8,000 astronomical objects stored in its memory, and high-rate slew speeds for automatic telescope pointing, CompuStar can take you on a tour of the universe that must be experienced to be comprehended. Even a partial listing of CompuStar's features and capabilities is too extensive to attempt here. Please write or call for additional information, pricing and delivery estimates, or send $10.00 cash, U.S., for our CompuStar Introductory Documentation Pkg.

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Each CompuStar telescope or retrofit system supplied by CTC includes: (1) an AC power supply; (2) a multi-function joystick controller; and (3), a 180-page "Stored Object Catalog", listing the data for each object stored in CompuStar's memory, and including page or plate cross-references to the most popular star atlases and catalogs, including Uranometria 2000 V1.

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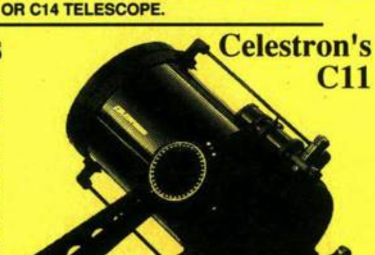

Celestron's C11

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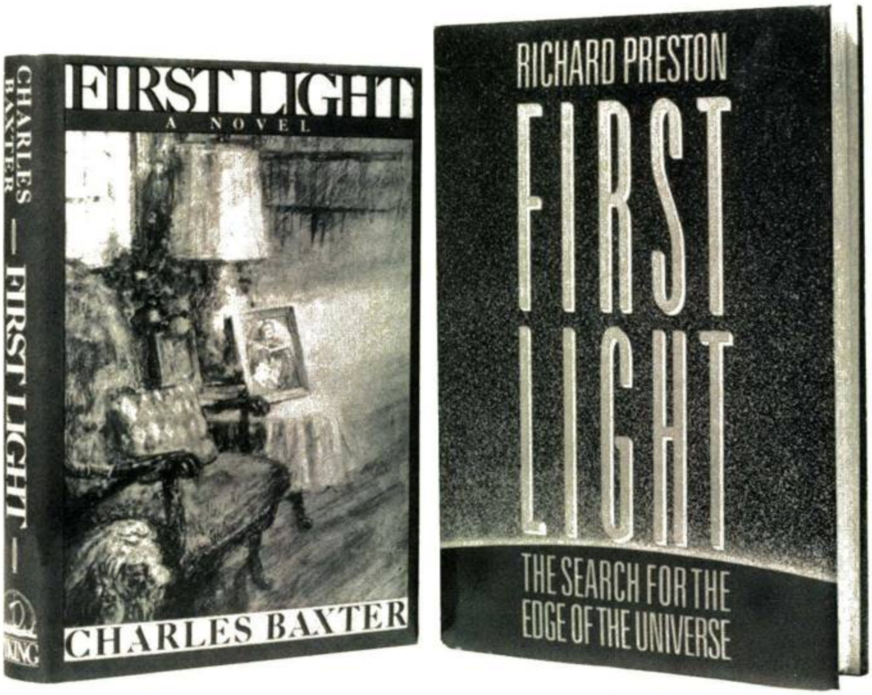
Searching for Beginnings: Two Approaches

First Light: The Search for the Edge of the Universe by Richard Preston, (Atlantic Monthly Press, 1987), ISBN 0-87113-200-1, hardcover, 257 pages, $18.95.

First Light by Charles Baxter, (Viking, 1987), ISBN 0-670-81701-5, hardcover, 286 pages, $17.95.

Charles Baxter's *First Light* is a novel; Richard Preston's, a piece of science journalism. Both are excellent books, rich in character and story, and both deal with contemporary astronomy at some of its farthest reaches.

Preston writes about two very different kinds of astronomical research currently being carried out on Palomar Mountain, about the astronomers doing the work, the instruments the astronomers are using, and the people who designed and built those instruments. In fact, he takes us right into the data room of the 200-inch Hale Telescope where astronomer Jim Gunn works frantically putting together a "kludge" to enable the four-shooter, a supersensitive CCD camera he designed, to record narrow ribbons of sky as they transit the field of the 200-inch and where later Gunn and Maarten Schmidt and Schmidt's assistant Don Schneider gape at their video screens as a seemingly endless stream of galaxies crosses from bottom to top. Schmidt, as principal investigator, Gunn, and Schneider are searching for "first light" — very distant, redshifted quasars that mark the outermost boundary of space and the farthest back in time that astronomers can see with the aid of their largest telescopes and most sensitive CCD cameras. They are trying to map the edge of the universe.


FIRST LIGHT
A NOVEL
CHARLES BAXTER
CHARLES BAXTER — FIRST LIGHT —
VIKING
RICHARD PRESTON
FIRST LIGHT
THE SEARCH FOR THE EDGE OF THE UNIVERSE

We are present, too, more than twenty years earlier when, on February 5, 1963, Maarten Schmidt first recognizes an extreme redshift in the spectrum of a starlike object and a colleague recognizes that he also had seen such a redshift in another object but dismissed it as impossible. Preston takes us with him as he follows the astronomers through their work days and nights. We hear their anxious mutterings, their banter, and their elated exclamations.

He takes us with him again when he visits a couple of astronomers engaged in a very different search with a very different instrument. Gene and Carolyn Shoemaker, a husband-and-wife team, are looking for Earth-crossing and Earth-approaching asteroids and dead comets, another kind of "first light" — primordial material, debris left over from the formation of the solar system — that could have a real impact on our home planet now. We join the Shoemakers as they drive from their home near Flagstaff, Arizona, across the Mojave Desert to Palomar, and we are with them in the dome of the aged and problem-plagued 18-inch Schmidt as they feed it "cookies" of film to expose, which Carolyn will later use to search for asteroids and comets (and as they feed themselves Oreos to stay warm).

Preston dips back into the lives of all the major figures involved in the searches he recounts, which is what makes his book so absorbing. He also takes us back to "first light" for the Hale Telescope and the 18-inch Schmidt. He dips back into the life of

George Ellery Hale, who in the 1920s conceived of the 200-inch telescope and initiated the project for construction of the "Big Eye." And he dips back into the life of Bernhard Schmidt, the German optician who in 1929 conceived of a telescope with a spherical mirror and a corrector that would enable the image formed by the mirror to be in focus everywhere on a circular piece of photographic film — the design used for the "Little Eye" on Palomar Mountain.

Also searching for beginnings of a sort is the main character in Baxter's novel, *First Light*. The story concerns a sister and brother, Dorsey and Hugh, an astrophysicist and a car salesman, respectively. Dorsey is searching for the beginning of the universe, and Hugh is searching for meaningful contact with Dorsey. The story is also about modern physics' search for knowledge and power, as articulated and symbolized by the brilliant and brooding Carlo Pavorese, Dorsey's dissertation director and her lover for a time and the father of her son.

Like Preston's, Baxter's book works by going backward in time. At the beginning of the novel Dorsey, her actor husband Simon, and her son Noah are en route from their home in Buffalo, where Dorsey is a physics professor at the university, to Minneapolis, where Simon has a part in a play. They stop to visit Hugh and his family at their home in Five Oaks, Michigan, Hugh and Dorsey's hometown. We observe the deep affection and close ties between the brother and sister in the midst of their very different family lives and careers.

From this point in their adult lives subsequent chapters take us farther back in time. We first meet Carlo Pavorese through a letter to Dorsey, then through an earlier phone call to her in Buffalo, and only later as her teacher and lover at a university in San Francisco. Next we see Dorsey and Hugh as teenagers, one bookish and excelling in school, the other handsome, sociable, handy, and athletic. Looking farther and farther back toward their beginnings, we see the child Dorsey and her parents enthralled in a solar eclipse, while Hugh feels left out and rejected. We hear Hugh being told to always care for his baby sister. Finally, we are with Hugh and his father when they visit the hospital where Dorsey has just been born and where Hugh sees her and touches her tiny hand for the first time.

Dorsey's work as an astrophysicist, like Maarten Schmidt's, is a search for "first light" in one of the several senses that term applies in these two books. She is searching, not by telescope but by mathematical equations, for the "missing mass" needed to make calculations related to the Big Bang yield a closed rather than an ever-expanding universe. Their story is also a search for a beginning of the relationship between Dorsey and Hugh, for the moment of "first light" through Dorsey's eyes.

The novel is also an ambitious attempt to explore the ramifications of modern physics. Carlo Pavorese, a student of Robert Oppenheimer, is obsessed with Oppenheimer's career; he takes it as emblematic of the inextricable involvement of light with darkness. In a letter to Dorsey he tells her about seeing the Trinity test, the explosion of the first atomic bomb near Los Alamos, New Mexico: "The light of the bomb, the first light like a momentary morning star . . . the first star that men had made." Humans' love of light, their quest to have it and to make it, is, Carlo sees, terribly costly. They will have to pay a high price for it.

This theme runs through Preston's book as well, though not as strongly. It surfaces in the stories of George Ellery Hale who, ill with a nervous condition, ended his days in retreat without ever seeing the 200-inch telescope, and of Bernhard Schmidt, a pacifist, who drank himself to death on

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the eve of World War II. The lives of Maarten Schmidt and Jim Gunn, of Carolyn and Gene Shoemaker, do not seem as dire as those of the men responsible for the "Big Eye" and the "Little Eye" through which they look out at the universe. But the visions of the universe they have formulated from what they see are vast and violent.

Preston's book gives a vivid sense of what the practice of modern astronomy is like, especially the interactions among colleagues and collaborators. Baxter's portrayal of Dorsey at work is less convincing. For one thing we are simply told she collaborates with her colleague over the phone or through the mail. But the novelist chooses not to crowd his main characters or obscure his plot or theme. Preston's book is crowded, but for the most part this doesn't cause confusion or the reader to lose interest. Only in the basement at Caltech where sophisticated electronic equipment is built, often from scavenged parts, are the characters a bit flat.

Altogether, both *First Lights* tell a great deal about modern astronomy and about people. Anyone interested in the actual practice of modern astronomy should read Preston's book; anyone interested in a human story that suggests some of the implications inherent in modern physics should read Baxter's novel. Read together, they illuminate each other.

— *Eleanor and Richard Berry*

A Resource for Experienced Astrophotographers

Astrophotography II by Patrick Martinez, (Willmann-Bell, 1987), ISBN 0-943396-13-1, paperback, 174 pages, $18.95.

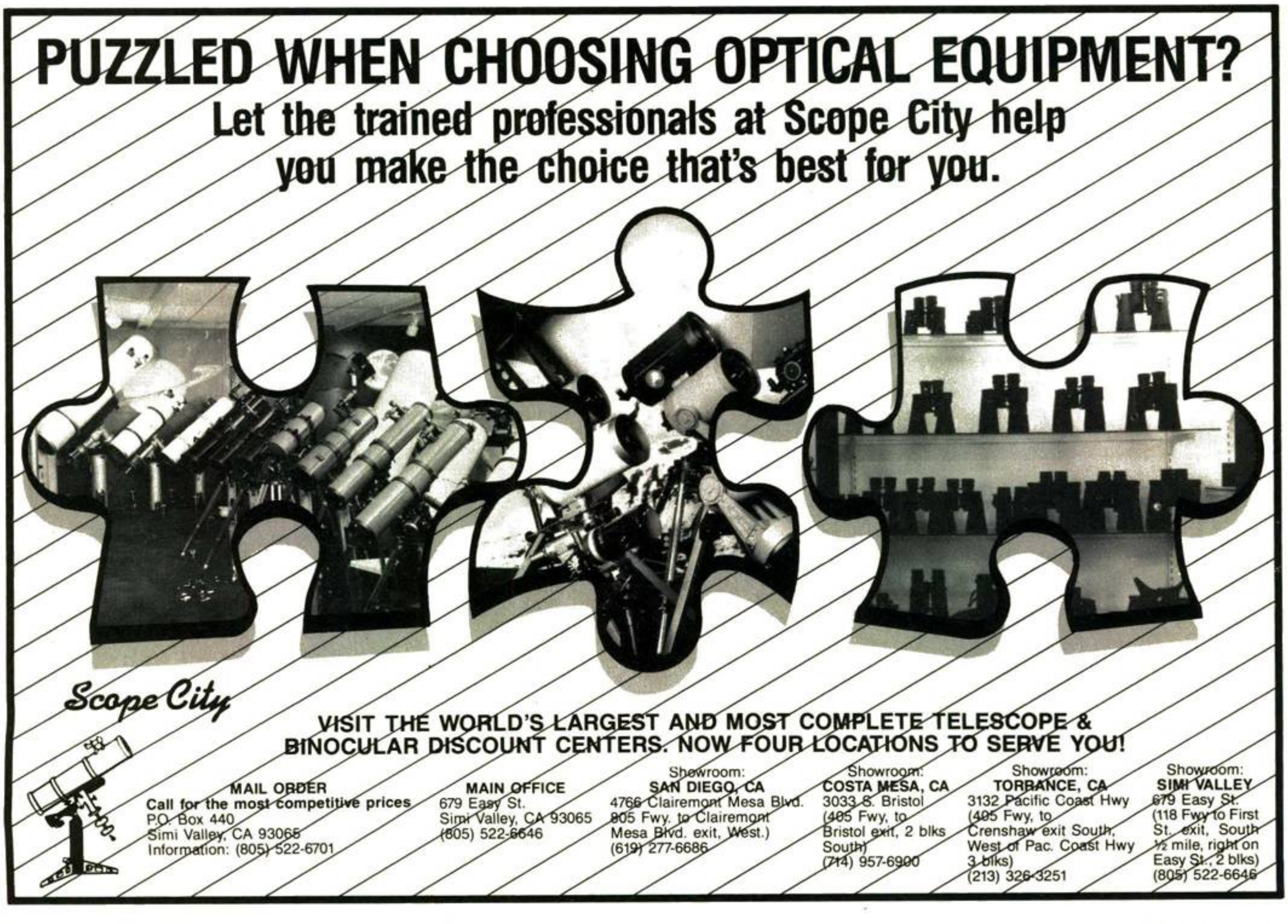
Although relatively short, this book contains nearly all the information needed for an astrophotographer to understand optical systems and how to select the best system to photograph celestial objects. It runs heavier on the mathematics of optical systems than most astrophoto books, but nearly everything included is useful and necessary.

It's tempting to say that because Martinez is French, the book proceeds logically from carefully derived first principles. But even if you neglect the subtitle, "Featuring the Techniques of the European Amateur," there's a flavor here that's unmistakably trans-Atlantic. A North American astrophoto book would assume the audience is unfamiliar with tackling a difficult subject without being babied along and would probably open with a chapter explaining how easy it all is. The reader would then be exhorted to take a few photos right away with a camera on a tripod.

Martinez, on the other hand, runs a sterner school. He insists — correctly I think — that you have to understand what happens inside optical systems before you can link the elements together intelligently. Where he can be, he's transparently simple — camera-on-tripod and prime-focus systems are explained clearly and directly — but the intricacies of afocal systems and eyepiece projection cannot be dealt with so quickly. If you can restrain your impatience to run out and *do something* immediately and are willing to work through his explanations with pencil and paper, this book will give you a clear understanding of how to assemble astrophotographic systems for the best effect.

Chapter one divides celestial objects into three astrophotographic categories: the Sun, the Moon and planets, and "faint objects," which means everything else. Martinez then talks about the different kinds of telescopes and explains how optics form an image. Mountings, resolving power, and aberrations finish off the chapter.

The second chapter covers photography without a telescope — tripod and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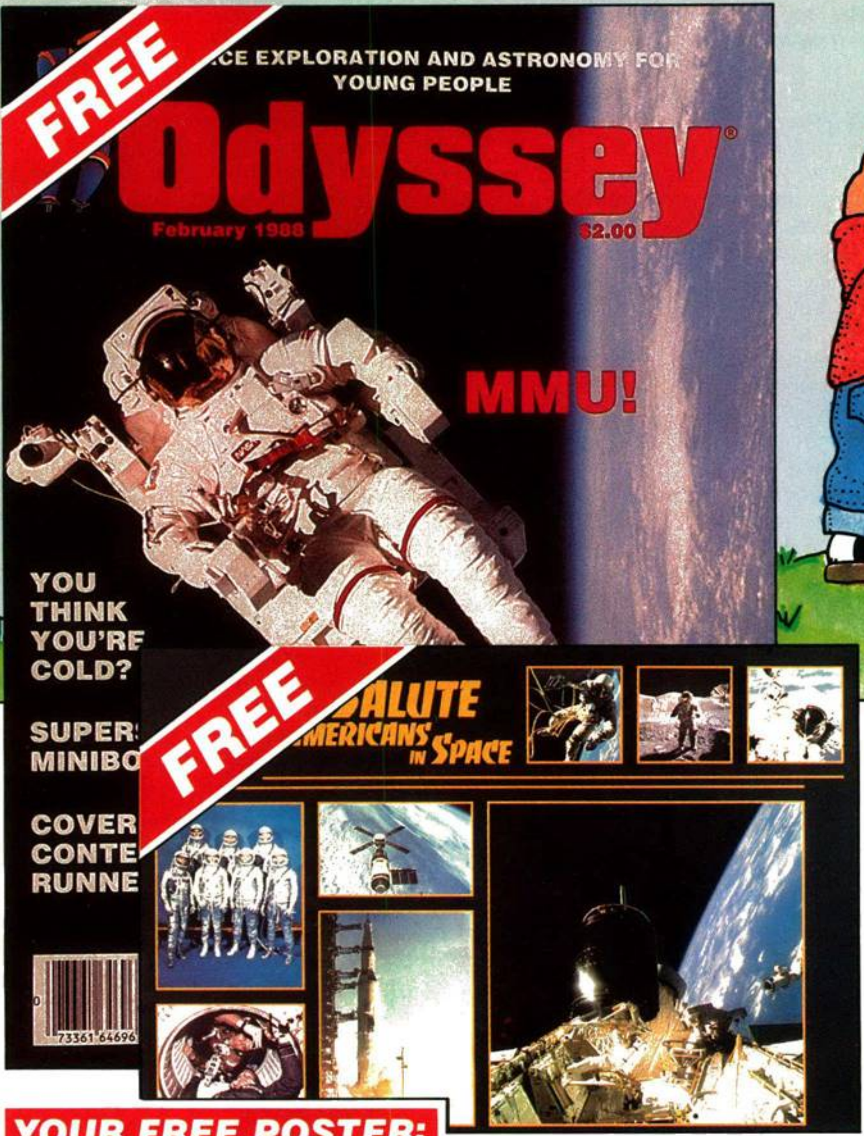

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piggyback. He shows you how to determine the maximum length of an exposure with a given lens before the stars trail noticeably and how to work out what your limiting magnitude is, theoretically and then in practice. The last part is on meteor photography.

Chapter three, however, comes to grips with the real stuff: prime-focus and projection systems. The author begins by making you work out the requisite magnification factor, given the angular size of the target object and how big you want it on film. This in turn leads you into choosing a system that gives the best results for that magnification. For anyone who goes astray in the mathematical thickets, there's an excellent table summarizing the results.

Films, developers, and filters are the subject of chapter four. We are told how the characteristic curve of a film indicates the film's contrast and which degrees of contrast are good and bad for certain subjects. (For instance, high contrast is best on planetary subjects, low on lunar ones.) Martinez also tells you how to expose the film so the object is best separated from the inherent fog of the film. I wish he had given a clearer idea of how to work out exposure, though, because this is a real bugaboo for many astrophotographers. Experience teaches you quickly, but giving the old empirical $E = F^2 / S \times B$ formula (together with a table of typical B values) might shorten the trial-and-error loop considerably.

With developers Martinez concentrates on how to pair off a given film with the developer the film is happiest with. (He provides the formulae for MWP-2 and POTA, two developers used in astronomy but unavailable commercially.) Here again, a highly useful table summarizes results. In this chapter the text's age (the French edition dates to 1983) becomes quite noticeable. Naturally, the new Kodak T-Max black and white films are ignored, but even the color section lists none of the recent high-speed color films aside from Fuji's. This part of the book should have been brought up to date.

Chapter five is on planetary photography, where questions of seeing and film resolution dominate. This kind of astrophotography is particularly difficult to carry off well. Although planets are relatively bright, you end up using high-magnification projection systems and may even need to guide! Atmospheric seeing is critical to good results, so Martinez has a clear discussion of it. After laying out all the problems, he has some level-headed suggestions for shooting lunar subjects as well as the planets at various magnification factors.

Solar astrophotography fills chapter six. The author sensibly recommends using over-the-aperture filters to keep problem-causing heat out of the instrument — although he might have noted that subdiameter filters can be combined with an aperture cap if you have a large scope and don't care to spend a lot of money on a full-size filter. Chapter seven is on faint-object (deep-sky) astrophotography and is replete with discussions of guiders, filters, combating light pollution, and color films. Chapter eight, "Some Techniques to Know," concerns polar alignment, focusing, and spectroscopy. It also contains a brief discussion of darkroom techniques.

You'll find a detailed outline of equipment types — telescopes, eyepieces, cameras — and their strengths and drawbacks in chapter nine. Three appendices (reflections on limiting magnitude, evaluating surface brightness, and determining the quality of seeing) finish off the text. A good index follows, although the extraordinarily detailed table of contents at the front of the work makes a pretty good second index too.

A pleasant, useful feature is the many excellent astrophotos illustrating the book. (All include full photo information.) With the exceptions of Jean Dragesco and perhaps Hans

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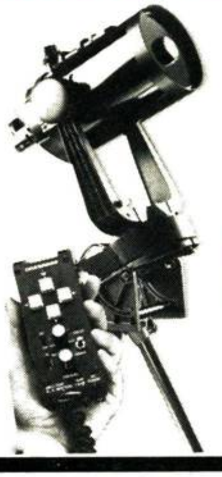

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Vehrenberg, the names will most likely be new to ASTRONOMY readers. Most photos are black and white, but there's a color section with thirteen photos that runs the entire gamut of celestial objects (except the Sun). The quality of these color photos is generally high, but several have an uncorrected greenish or reddish color in the sky background.

A few typos and strange word choices make me suspect the translator isn't entirely at home in amateur astronomy, but the mistakes are so obvious that no one is likely to be more than momentarily confused.

I've explained why the book is good, but there are some areas I'd like to see improved in a second edition. First, Martinez says relatively little about darkroom technique. He tells you how to dodge and burn in areas on a print and how to make unsharp masks and integration prints, but he doesn't discuss papers and their developers, processing for maximum quality, or even such basics as annotating the backs of prints with processing (and celestial object) details. Also, the darkroom discussions center wholly on black-and-white work, almost entirely ignoring color. Even if he chose to avoid color-darkroom details, Martinez could have offered some practical advice for those who are forced to use commercial photofinishers.

Second, anyone scouting for specific equipment recommendations is going to be disappointed. Telescope and eyepiece types are discussed in terms of design strong points, but brand names are avoided. The same goes for guiders, camera adaptors, and mountings. While the focus on principles is good as far as it goes, it's really only half the story. Adding some brand names wouldn't have hurt and would lend a necessary touch of concreteness. With cameras he's more forthcoming, telling you which models have interchangeable focusing screens and auxiliary viewer-magnifiers. (But he doesn't warn owners of all-electronic cameras about the troubles they can expect when their batteries give out under conditions of long exposure, cold, or both.)

The publishers indicate that this is an intermediate to advanced level book (at the introductory level, they offer *Astrophotography* by Barry Gordon). I think that judgment's fair. The ideal reader of Martinez' book is the seasoned amateur astronomer already familiar with general photography and comfortable in the darkroom who is now interested in trying astrophotography. The last person who should read it is someone fresh to the hobby, who has a new camera and telescope and who has vague yearnings to "take sky pictures." The beginner would do better by beginning with one of several introductory books such as Gordon's, mentioned above, or Michael Covington's.

In summary this is a book I recommend, though it's not for every astrophotographer.

— *Robert Burnham*

Stars

Circumstellar Matter, edited by I. Appenzeller and C. Jordan, (D. Reidel, 1987), ISBN 90-277-2511-X, hardcover, 607 pages, $109.

The Classification of Stars by Carlos and Mercedes Jaschek, (Cambridge University Press, 1987), ISBN 0-521-26773-0, hardcover, 413 pages, no price given.

Interstellar Processes, edited by D. J. Hollenback and H. A. Thronson, Jr., (D. Reidel, 1987), ISBN 90-277-2482-2, hardcover, 807 pages, $139.

Instabilities in Luminous Early Type Stars, edited by H. J. G. L. M. Lamers and C. W. H. de Loore, (D. Reidel, 1987), ISBN 90-277-2522-5, hardcover, 290 pages, $69.

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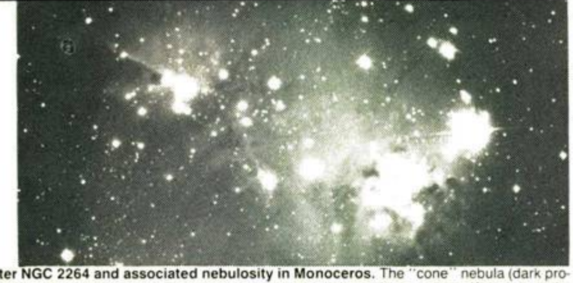

Open Cluster NGC 2264 and associated nebulosity in Monoceros. The "cone" nebula (dark protrusion) is to the left and bright star S Monocerotis is to the right; north is to right. This nebulosity has very low surface brightness, and reliable visual sightings of the cone nebula are not yet reported; try a LUMICON H-Beta filter or a LUMICON Oxygen-III Filter. NGC 2264 is best photographed with a LUMICON DEEP-SKY Filter. Photo by Bill Sorrells, 16" f/5, hyper 2415 film, 40 minutes using a LUMICON 2" EASY-GUIDER™

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The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission = 85-95%.

"I CAN SEE THE OWL NEBULA!"

Tom Kramer saw the Owl Nebula, M-97, for the first time using a LUMICON UHC Filter. He stated, *"I had never seen M-97. . . I attached the UHC Filter and tried again. M-97 was right there. I could not believe it! The UHC Filter should be standard equipment."* **Tom Kramer, Sayville, NY**

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter**

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 90-95%.

	Standard	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces		$59.50
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces		$79.50
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS		$119.50
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	$99.50	$119.50
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)		$299.50
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	$79.50	$99.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	$159.50	$199.50
Set of Both 1¼" **DEEP-SKY** and **UHC Filters** (Save 11%)		$159.50

LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. ... **1¼" $89.50** ... **48mm $189.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines ... **1¼" $99.50, 48mm $199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm ... **$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece ... **$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece ... **$20.00**

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount .. **$45**
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Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	H-Alpha	(MV)
46, 48, 49mm	$35.00	$29.00
52, 55, 58, 62mm	$45.00	$35.00
67, 72, 77mm	$52.00	$45.00
82mm	$55.00	

Hypered 2415 film, 36 exp . . . **$10.95** . . . **3/$29**

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DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of nonflammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

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All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.
U.S. Patent #4,448,500

NEWTONIAN EASY-GUIDER™

Full aperature. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER ... **$169.50**
3X Relay Diagonal (see photo) ... **$79.50**
Illuminated reticle eyepiece system .. **$89.50**
Guider for Hasselblad **$350,** Mamiya 645 **$199**

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For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**

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For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

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Adapter for Hasselblad **$195,** Mamiya 645 **$96**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece ... **$89.50**
Lumicon 12mm eyepiece system has adjustable L.E.D. illumination, dual crosslines, battery pack.
2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector** **$219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination motor (state telescope) .. **$70**
NEW Deluxe Digital Qtz. Drive Correc. **$298**

SR1600
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NEW
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HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	Exposures	Price
2415, Ultra-fine B&W, red sens.	36	$10.95
SRV3200, fastest of all, color neg	24	$13.95
Konica SR1600, very fast, fine gr.	24	$12.95
Konica SR400, fine grain color neg	12	$10.95
3M 1000, fastest slide film	12	$12.95
Fujichrome RD100, fine grain slide	24	$12.95
D-19 B&W Developer	1 gal.	$6.95

NEW LUMICON® PRODUCTS

LUMICON, 2111 Research Dr., #5
Livermore, CA 94550 (415) 447-9570

NEW! NON-ROTATING HELICAL FOCUSER

LUMICON® DELUXE NON-ROTATING HELICAL FOCUSER on a 6'' telescope.

LUMICON has just designed a deluxe smooth helical focuser with non-rotating 2'' i.d. eyepiece holder. It has a vertical travel of 1¼'' and a very low profile only 1½'' high. It is CNC machined, black anodized, and a perfect match to LUMICON EASY-GUIDERS.

Select your desired base-plate shape! Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 20'' OD, SUPER-FINDER base plate.

LUMICON Deluxe Helical Focuser ...	$79.50
3 handles (see photo)	$12.95
Helical focuser with 3 handles	$92.40
2''/1¼'' **adapter** w/48mm filter threads	$20.00
2'' LUMICON EASY-GUIDER	$169.50

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These adapters allow high magnification photography of the Moon and Planets using eyepiece projection. They may be used without any eyepiece for prime-focus photography. All adapters use standard camera T-rings.

Tele-Extender for Meade or Celestron SCT.	$32
1¼'' Basic Camera adapter, 2 part system	$32
0.96'' Basic Camera adapter, 2 part system	$32
1¼'' prime Focus adapter, fits 1¼'' focuser	$22
0.96'' prime Focus adapter, fits 0.96'' focuser	$22
Camera T-ring, specify 35mm camera type	$12

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat. The deluxe SUPER-FINDER uses an 80mm, F=500mm air spaced achromat.

1¼'' 50mm Finderscope **$59.50**, right-angle	$89.50
1¼'' straight-thru 80mm SUPER-FINDER ...	$169
1¼'' right-angle version, w/star diagonal	$195
2'' right-angle version, non-rotating focuser ..	$199
1¼'' Deluxe right-angle Super-Finder*	$279
2'' Deluxe right-angle Super-Finder*	$309
25mm Cross-hair 1¼'' eyepiece (12X)	$29
*1¼'' Star Diag. **$32**, 2'' Star Diag., silver,	$145
1¼'' Amici Prism diag. for correct left-right views	$59.50

2'' ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2'' operation. They allow use of 2'' accessories, such as the LUMICON 2'' EASY-GUIDER for photography. They also allow use of 2'' eyepieces and/or 2'' star diagonal for viewing.

2'' adapter for C-8, Meade 2080, etc....	$26.00
2'' adapter for Criterion 4000, 8000 ...	$26.00
2'' adapter for C-80, C-90, C-100	$39.50
2'' adapter for C-70, C-80F, C-90F, C-100F	$39.50
2'' Accessory adapter for Comet Catcher*, C-6*, Meade 310, 320 refractor	$30.00
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COMA CORRECTOR MULTIPLIER - 2'' BARLOW

These custom-designed LUMICON lenses correct aberrations in f/4 to f/5 Newtonians, and thread directly into LUMICON 2'' Easy-Guiders. The LUMICON Coma Corrector/Field Flattener improves photographic star images for fast Newtonian telescopes by correcting coma and flattening the field. Off-axis star images are much smaller, making off-axis guiding easier, and reducing the off-axis star image size in photos. The LUMICON Multiplier/Field Flattener multiplies the image scale by 1.8X (f/4.5 becomes f/8) with the included extension tube (1.5X w/o extension). The multiplier may also be used visually as a highly corrected 2'' Barlow lens. Lens designs are optimized for f/4.5 and all surfaces are multi-coated.

48mm Coma Corrector/Field Flattener	$285.00
1.5X/1.8X Multiplier/Field Flattener .	$195.00
LUMICON 2'' Easy-Guider (St. camera)	$169.50

VIEWING ADAPTERS

2''/1¼'' Adapter, threaded 48mm filters ..	$20
2''/T - Thread adapter, threaded 48mm ..	$25
T - Thread/1¼'' adapter. Converts telephoto lenses for viewing as finderscopes	$25

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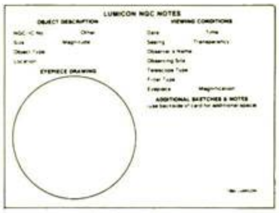
1.0'' long Thread-in extension tube	$12.00
1-2½'' long, threaded for 1¼'' filters	$16.00
4½'' long extension tube, 1¼'' i.d.	$25.00
2'' i.d. Extension tube, 3'' long, threaded for 48mm filters, adds 1.6-3.0''	$26.00

48mm COLORED GLASS FILTERS

These 48mm Filters thread into LUMICON EASY-GUIDERS and most 2'' eyepieces. Use adapter for 1¼'' eyepieces. AR Coated.

Filter:	Bandpass	Trans	Price
Ultraviolet	320-420nm	85%	$35
Minus Violet	420nm-IR	96%	$29
Blue Tricolor	340-470nm	80%	$35
Hi Perf. Blue	300-540nm	95%	$35
Yellow	480nm-IR	98%	$18
Green	490-590nm	60%	$18
Orange	560nm-IR	98%	$18
Red	600nm-IR	98%	$18
H-Alpha Pass	640nm-IR	95%	$35
Cyan	340-580nm	95%	$59


LUMICON NGC NOTES
OBJECT DESCRIPTION
VIEWING CONDITIONS
EYEPIECE DRAWING
ADDITIONAL SKETCHES & NOTES

NGC NOTES

These handy **NGC NOTES** are stiff 4''X5½'' cards. the **NGC NOTES** fit in your hand and are ideal for making notes and sketches while observing at the eyepiece. Making sketches **greatly improves** your observing skills and also gives you a permanent record. Get 200 **NGC NOTES** for Messier objects; NGC object observers should get 400-800 **NGC NOTES.**

NGC NOTES, Pack of 200	$9.95
Pack of 400 **$17.95** Pack of 800	$32.95

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New Meade MTS telescopes in stock!
6'' f/4 **$595**, 8'' f/4 **$895**, 8'' SCT **$895**, 10'' SCT **$1495**
Call for details on available options for MTS telescopes

NEW! 2080/LX5 w/MCOG $1685
MEADE 2120/LX5 w/MCOG ... $1999

The most advanced Schmidt-Cassegrain telescope available! *Standard equipment* includes dual-axis hand-held electronic command center, 2'' mirror star diagonal, 9X60mm polar viewfinder, multi-coated/enhanced optics, 26mm Super Plossl, tripod and wedge.

#39 Electric declination for 2080 or 2120/LX5	$109
Dew shield-essential 8'' (#712) **$65**; 10'' (#710)	$98
Accessory shelf for field tripod ($40 list)	$28
LUMICON EASY-GUIDER/Rich-Field viewer: for 2080 (f/6 operation) **$225**; for 2120 (f/4-f/10 operation)	$395
Computer control system, 8000 object memory	$1495

8''
LX5
$1685
10'' LX5
$1999
10'' LX3
$1799

Meade 8'' Model 2080/LX5: Shown with *standard-equipment* 9X60mm finder, dual-axis controller, 2'' Diagonal Mirror, Equatorial Wedge, Field Tripod.

NEW! MTS TELESCOPES

8''
$989
w/
MCOG
10''
$1599
w/MCOG

Meade 8'' and 10'' Schmidt-Cassegrain Modular Telescope Systems (MTS) with optional drives.

Standard equipment includes 8'' or 10'' f/10 Schmidt-Cassegrain telescope with 6X30mm finder (SC8) or 8X50mm finder (SC10), 1¼'' star diagonal, MA 25mm 1¼'' eyepiece, equatorial fork mount with latitude scale and pier with legs.

MTS-SN6, 6'' f/5 Schmidt-Newtonian **w/MCOG**	$698
MTS-SC8, 8'' f/10 Schmidt-Cassegrain **w/MCOG** ...	$989
MTS-SN8, 8'' f/4 Schmidt-Newtonian **w/MCOG**	$989
MTS-SC10, 10'' f/10 Schmidt-Cassegrain **w/MCOG**	$1599
#788 Electric motor drive (115V/60Hz) for viewing .	$149
LX3 Quartz Drive w/hand controller for photography	$495
Manual Dec. Control, #66A for SC8 **$56,** #66C for SC10	$72
#38M Electric Declination Motor (requires #66A or #66C)	$99
#43 Drive Corrector (runs #788 off a 12VDC battery)	$99
#109 Setting Circle Set, with pointers	$39

See below for detailed viewing and photography options.

4'' MEADE 2045 w/table tripod $595

4'' f/10 Meade 2045/LX3 w/quartz drive	$795
#36 dual-axis cont. (LX3) **$99,** #38A dec. motor	$99
Wedge & field tripod for Meade 2045 ($380 list)	$298
Dew shield ($80 list) .... **$55;** Solar Filter	$95

FILTERS STOP POLLUTION

LUMICON UHC Filter™ for nebulae. Standard 1¼''	$79
Prem 1¼'' **$99;** Std 48mm **$159.50;** Prem 48mm	$199.50
LUMICON Deep-Sky Filter™, 1¼'' Premium ...	$79
48mm Prem Deep-Sky **$119.50, $99.95** w/Easy-Guider	
Adapter for viewing w/1¼'' eyepiece	$20

PHOTOGRAPHY ACCESSORIES

LUMICON Newtonian Easy-Guider, 1¼'' or 2''	$169
LUMICON Cassegrain EASY-GUIDER for Meade 2045, 2080/LX5 and 2080/GEM (state camera)	$225
Illuminated reticle eyepiece & battery pack	$89.50
Dual-axis Drive corrector	$219

These Meade Telescopes are complete and ready for viewing.

They include telescope with all coated optics for high transmission, mount, tripod or pier with legs, motor drive (except models 6600, 8800, GEM series). Finderscope, at least one eyepiece, and complete instructions. Call or write LUMICON for full technical information. MCOG means multi-coated enhanced optics group.

MEADE NEWTONIAN TELESCOPES

16'' f/4.5
MEADE
DS-16A
only
$1975

Note: Astrophotographers should order optional sealmaster ball bearings for the DS-16A (add $229).

Model 6600, 6'' f/5 w/1¼'' focuser, 6X30 finder	$685
Model 628c, 6'' f/8 w/motor, 2'' focuser, 8X50 finder	$798
Model 645c, 6'' f/5 w/motor, 2'' focuser, 8X50 finder	$829
Model 8800, 8'' f/4.5 w/1¼'' focuser, 6X30 finder	$895
Model 826c, 8'' f/6 w/motor, 2'' focuser, 8X50 finder	$975
Model DS-10A, 10'' f/4.5 w/motor, 2'' focuser ..	$995
Model DS-16A, 16'' f/4.5 w/motor, 2'' focuser .	$1975
Sealmaster ball bearings for DS-16A, recommended! **add**	$229
Finderscope for DS-10A, DS-16A, 8X50mm incl. mount	$109

All foreign orders add 6% ($8 minimum). California residents add 6% tax. Prices subject to change w/o notice. Set Meade and LUMICON Catalogues $4. **LUMICON, 2111 Research Dr., #5, Livermore, CA 94550.** Call **(415) 447-9570** for information & orders. Store Hours: M-F 9am-5pm; Sat 11am-3pm. All telescopes shipped F.O.B. Livermore.

Our Cosmic Horizons — Part Three:

The Structure of the Visible Universe

by Stephen A. Gregory

In part two of the series Our Cosmic Horizons we learned that all we can see in the form of planets, stars, and galaxies makes up only 10 percent of the total matter content of the universe. The remaining 90 percent, astrophysicists estimate, consists of "dark matter," ubiquitous but as yet undetected material that not only binds galaxies and clusters of galaxies but may even be responsible for forming them.

So what can the distribution of bright matter — comparatively no more abundant in the universe than algae floating on the surface of a pond — tell us about the universe as a whole? For one thing, the arrangement of bright matter gives us some idea of the universe's overall structure, which might provide links to events that occurred at the subatomic level in the Big Bang.

In part three of our series astronomer Stephen A. Gregory explains that the picture emerging from extensive galaxy surveys shows the universe is made up of an intricate network of interconnected galaxy clusters, called superclusters, strung across millions of light-years. Superclusters in turn outline equally large areas of seemingly empty space: voids. Astronomers are just beginning to grasp what these large-scale structures can tell us about the history and the future of the universe.

What are the largest organized systems in the universe? How did these large-scale structures form? At what scale is the universe smooth? Of the many fundamental questions cosmologists ask about the universe, these three are currently receiving a great deal of attention. If we knew the answers to these questions, we would have a solid understanding of the present state of the universe as well as of how the universe formed and evolved.

We can begin to formulate answers or at least rule out some of the possibilities by studying the distribution, masses, and gravitational behavior of galaxies, which are collections of hundreds of billions of stars. Along with the stars (half of which probably have planetary companions), galaxies are composed of dust, gas, and dark matter.

Although galaxies are the fundamental observable entities in cosmology, astronomers have known practically since galaxies were first recognized in the early 1920s as extragalactic star systems that galaxies congregate into larger systems called clusters. How and why galaxies form clusters instead of being distributed uniformly across the universe is one of the central issues of cosmology.

Galaxy clusters range in population from a few tens of galaxies (usually referred to as groups) to dense clusters containing from fifty to a thousand or more members. But the important debate that went on for several decades concerned whether or not galaxy clusters grouped into even larger systems, termed superclusters, and if these second-order systems grouped into third-order systems and so on up the hierarchical chain.

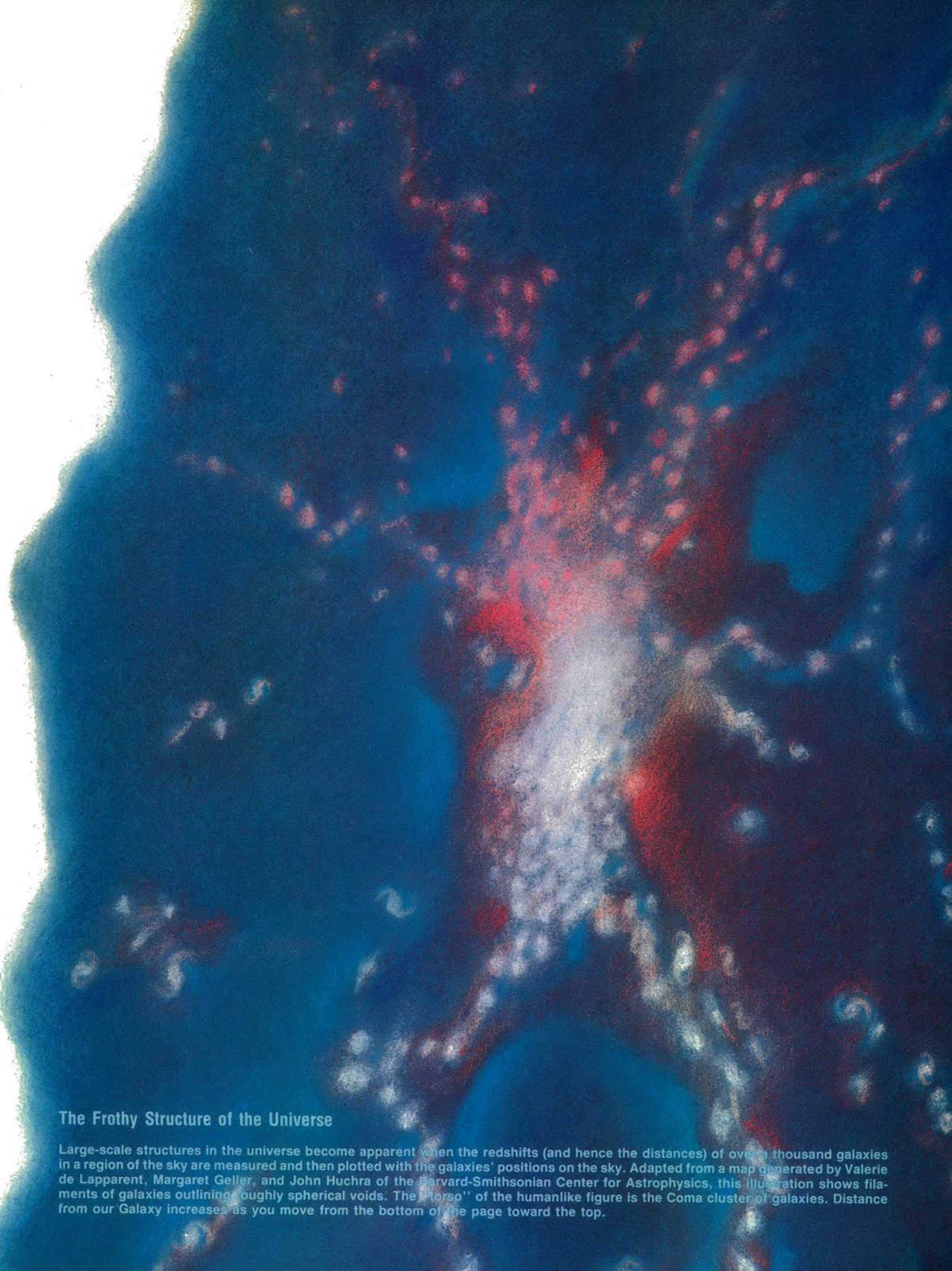
Edwin Hubble, one of the greatest figures in modern astronomy, lent his considerable weight in the mid-1930s to the idea that the universe is quite smooth and homogeneous — in other words, free of "lumpy" large-scale matter like superclusters. There was little observational evidence to make anyone think otherwise, yet there were two distinct camps. On one hand, Hubble believed clusters of galaxies could exist, but not superclusters. On the other hand, several astronomers such as Harlow Shapley, Clyde Tombaugh, Gerard de Vaucouleurs, George Abell, and C. D. Shane suspected that superclusters existed, but they had no strong observational evidence. So the issue sat for a few decades.

Then in the 1950s Gerard de Vaucouleurs studied the Local Group of galaxies and perceived it was part of an immense flattened cluster of galaxies that included the Virgo Cluster and about thirty other small groups. The Local Supercluster, as it was called, was considered the prototype of superclusters. We are located within the Local Supercluster, so it is difficult to ascertain the supercluster's overall structure because observational data needs to be taken from the whole sky. It's like trying to determine the shape of a vast amusement park by surveying the grounds from one of the rides.

The existence of the Local Supercluster provided a strong case for the existence of other superclusters. In 1978 Laird Thompson and I first convincingly demonstrated the existence of just such an external supercluster, one containing the rich clusters of galaxies in Coma and Abell 1367, as well as several looser groups of galaxies. Discoveries of superclusters in Hercules and Perseus soon followed.

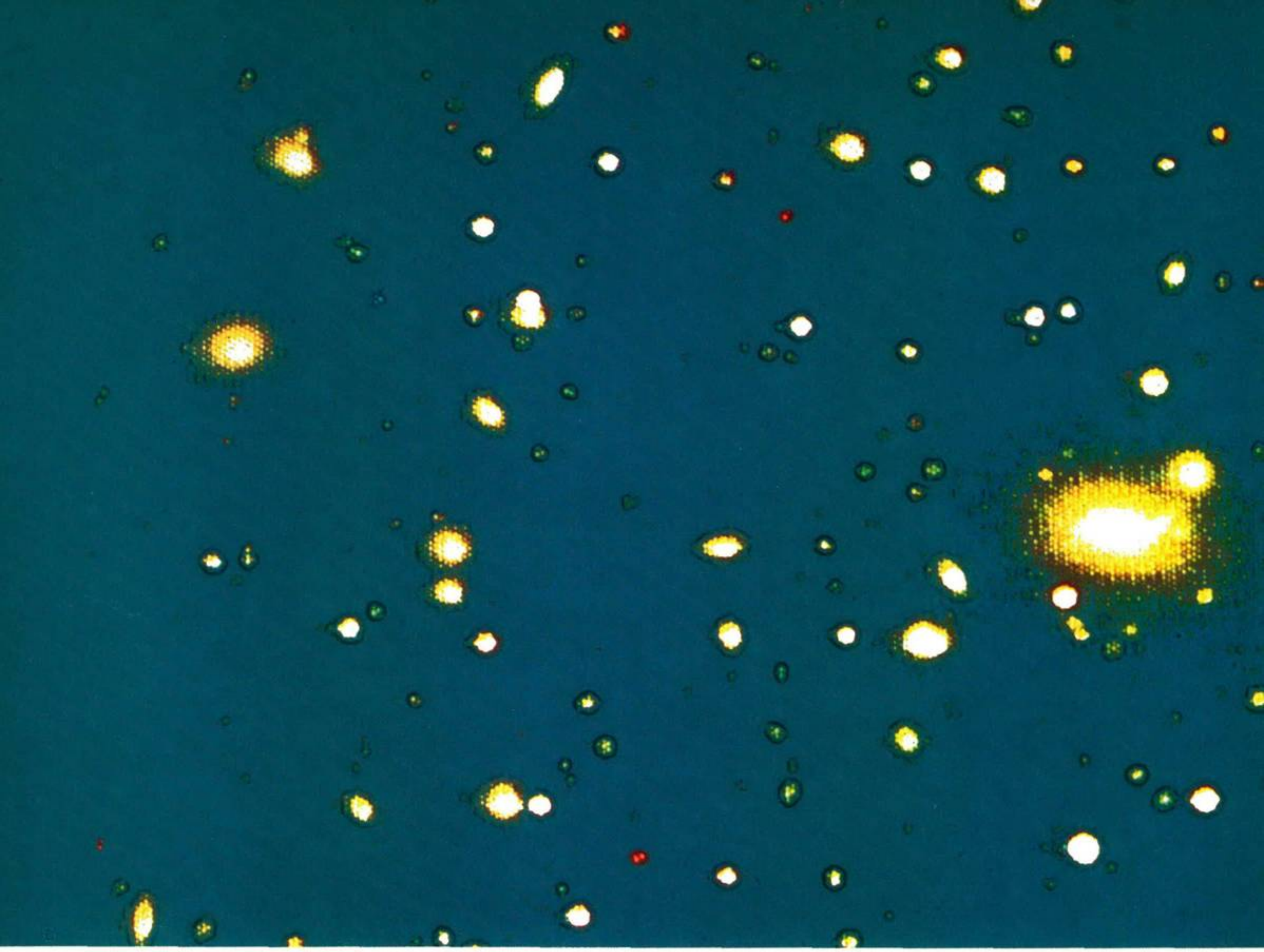
More surprising than the discovery of superclusters,

Illustration by Craig Smallish



The Frothy Structure of the Universe

Large-scale structures in the universe become apparent when the redshifts (and hence the distances) of over a thousand galaxies in a region of the sky are measured and then plotted with the galaxies' positions on the sky. Adapted from a map generated by Valerie de Lapparent, Margaret Geller, and John Huchra of the Harvard-Smithsonian Center for Astrophysics, this illustration shows filaments of galaxies outlining roughly spherical voids. The "torso" of the humanlike figure is the Coma cluster of galaxies. Distance from our Galaxy increases as you move from the bottom of the page toward the top.



however, was the revelation of vast regions between these superclusters that appeared entirely empty of galaxies. The term "void" has since been attached to these empty regions. Voids caught astronomers off guard. Conjectures about very large, massive structures are perfectly natural, but it is not as natural to speculate about emptiness.

Mapping the Universe

To map such vast structures, astronomers need to know the distances to the galaxies. Only when distance is plotted with sky location — thereby yielding a three-dimensional distribution of galaxies — do the galaxies sort themselves into clusters and superclusters.

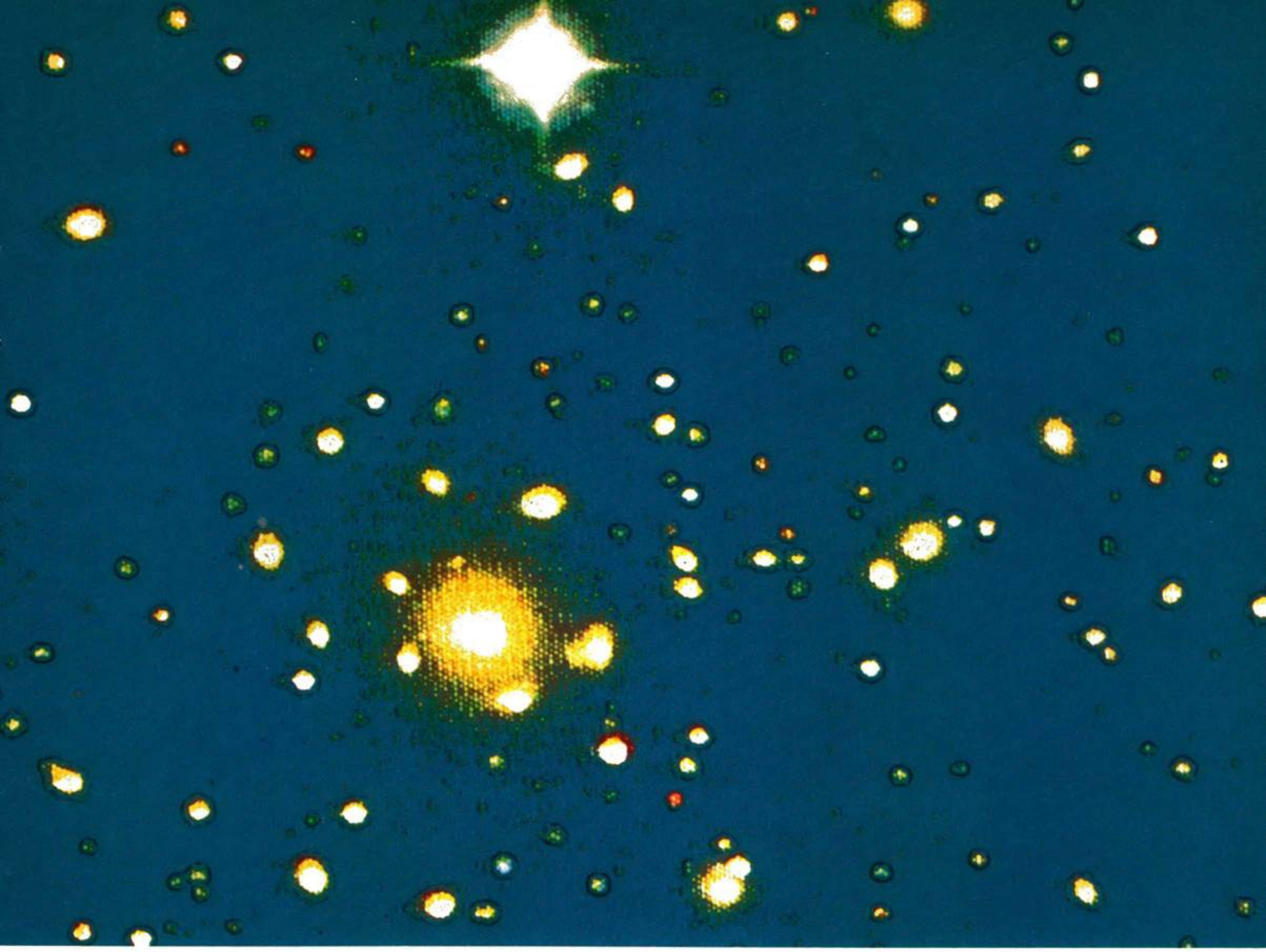
The principal tool for plumbing the depths of the universe is the redshift survey. The term redshift refers to a more general wave phenomenon called the Doppler effect, which is the change in the frequency of any wave phenomenon — sound, light, and all other high- or low-energy forms of electromagnetic radiation — because of the motion of the source. A redshift survey is a collection of redshift measurements of all the galaxies down to a certain magnitude limit in a certain area of the sky.

Redshift particularly applies to objects receding from us. If an astronomical object is moving away from an observer, the observer detects the light from that object at longer wavelengths than the object originally emitted: the object's spectral lines are shifted toward the red end of the spectrum relative to the lines in a standard laboratory spectrum. The faster an astronomical source moves away from the observer, the longer its wavelengths and the redder it appears.

In 1929 Hubble had showed there is a direct relationship between a galaxy's distance from our Milky Way Galaxy and the galaxy's redshift: almost all galaxies are moving away from one another. These observations prompted the astounding revelation that the universe is expanding.

Thus, by measuring the redshifts of galaxies the distances to those galaxies can be determined. When the distances of the galaxies are plotted on the sky, the result is a three-dimensional map that shows which galaxies belong to what cluster.

In Hubble's day, redshift observations were exceedingly time-consuming. Exposures to record the redshift of a single galaxy often lasted several days. Great care had to be taken in closing the shutter during the day (to prevent fogging of the photographic plate), and the plate had to be repositioned exactly as it was during the previous night's exposure. The observation was made by passing the light of the galaxy's bright central region onto a reflecting diffraction grating and recording the resulting spectrum on a photographic plate. (A diffraction grating is a mirror with thousands of fine lines etched upon its reflecting surface. Although it disperses white light into a spectrum of colors much as a prism does, a diffraction



grating is better suited for most astronomical applications because it produces exceptionally sharp spectral lines for each resolvable wavelength.)

Because most of a galaxy's light comes from stars, the galaxy's spectrum is a composite of the spectra of billions of stars. A typical galaxy spectrum is a K-type absorption line spectrum. The "K" designation indicates that the dominant stars are relatively cool: dark absorption lines are produced when the atomic features characteristic of the various elements in the stars' photospheres are fainter than the surrounding continuum radiation. By measuring how much the prominent absorption lines are shifted toward longer wavelengths, we determine the galaxy's redshift and distance (by invoking Hubble's law, which says a galaxy's recessional velocity is proportional to the galaxy's distance).

Wholesale Redshift Surveys

To meaningfully investigate questions of the large-scale distribution of galaxies, astronomers must measure the redshifts, and hence the distances, of hundreds or, better still, thousands of galaxies.

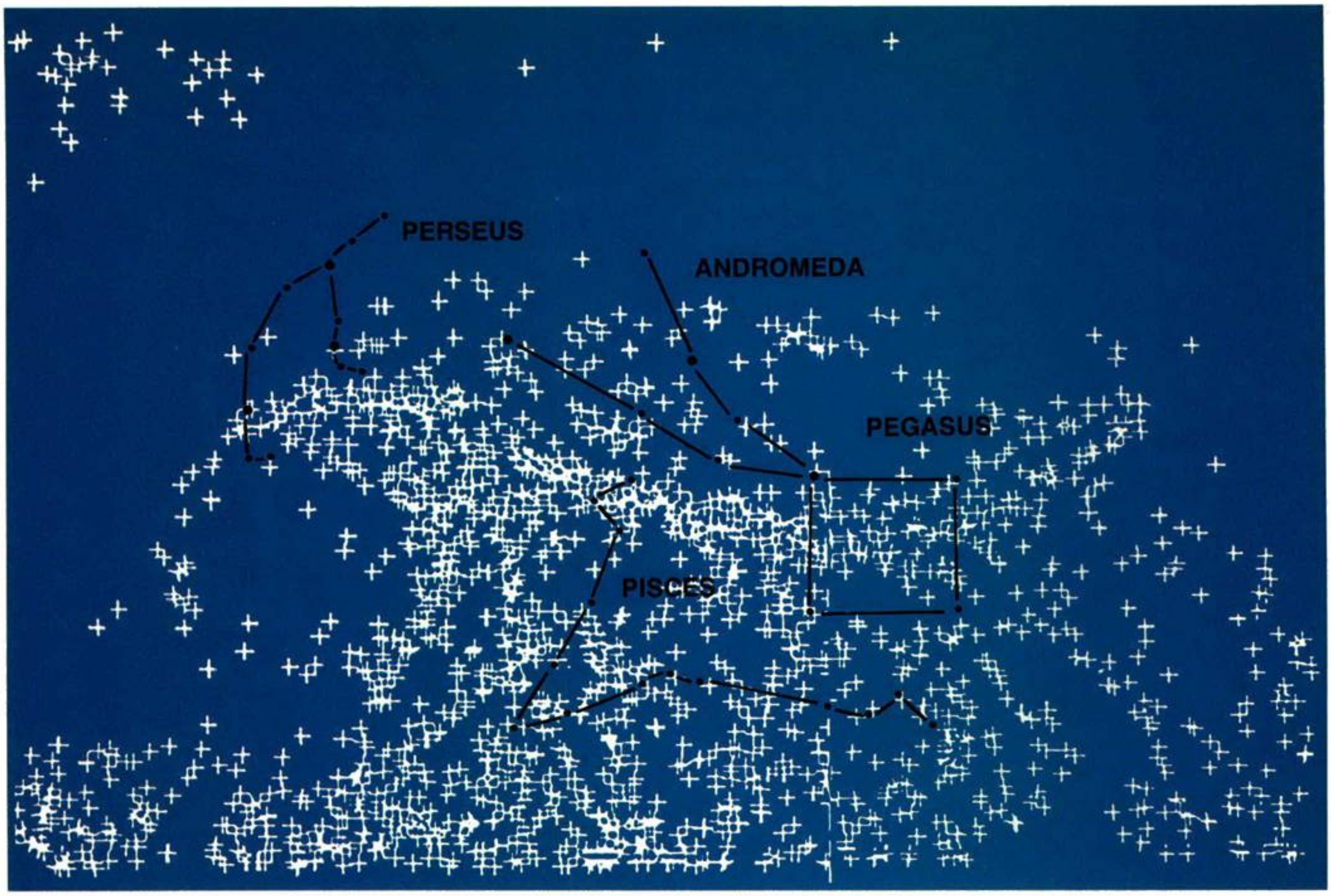
Redshift surveys at this scale have only been possible during the last fifteen years. The greater efficiency is largely a result of improvements in image technology. At least two innovations in this field have enabled the modern observer to obtain a better spectrum of a galaxy in half an hour than Hubble could in three or four nights.

A Congregation of Galaxies

Over two hundred galaxies are visible in this photograph of the central region of the Coma galaxy cluster. Astronomers believe the cluster may contain as many as 10,000 galaxies if dwarf ellipticals are taken into account. This rich cluster, which is roughly 10 million light-years in diameter, merges smoothly into the nearby rich cluster Abell 1367. National Optical Astronomy Observatories.

The first is the development of image intensifiers. These devices convert the faint light from an incoming image into an equivalent image of electrons. These electrons are then accelerated and allowed to fall on phosphor, which converts the image back into light. As a result of this process, the final image may be thousands of times brighter than the original, and brighter images are easier and faster to obtain good spectra from.

The second innovation is using semiconductor devices to record galaxy spectra rather than photographic plates. The semiconducting devices typically have a large number of tiny capacitors that accumulate charge as light falls on them. At the end of an exposure the charge array can be read out directly to a computer and analyzed. Reticons and charge-coupled devices (CCDs) are examples of such modern detectors, and they can be as much as one hundred times more sensitive to light than photographic plates.



Many research groups are conducting redshift surveys. Groups at the Harvard-Smithsonian Center for Astrophysics, Mount Wilson and Las Campanas observatories, Carnegie Institution, the University of Michigan, the University of Oklahoma, the University of New Mexico, and Steward Observatory are conducting visible light surveys with conventional telescopes. In the Southern Hemisphere the Anglo-Australian Telescope, the European Southern Observatory, and the Observatorio Nacional in Brazil are looking for large-scale structures in the southern skies.

Some redshift work can also be accomplished with radio telescopes by using the hydrogen 21-centimeter line. Prominent studies have been made by groups at the National Radio Astronomy Observatory/University of Hawaii and at Cornell University's National Ionospheric Observatory at Arecibo, Puerto Rico.

These tools and methodologies enable astronomers to measure the dimensions of the universe to a degree impossible two decades ago. Nevertheless, there are some practical limitations to our observations that we must deal with if we are to understand what we are seeing.

One fundamental problem with redshift surveys lies in the sample of galaxies selected for the study. Ideally we would like to observe *all* galaxies in a given volume of space, but because of the large number of very faint dwarf galaxies, this goal is impractical. Except for those nearby systems, dwarf galaxies are too faint to be adequately studied.

The next best choice is usually a magnitude-limited sample in which all galaxies in a given area of the sky are observed down to some convenient cut-off magnitude. Usually the five-volume *Catalogue of Galaxies and Clusters of Galaxies* is consulted because it lists about 32,000 galaxies with reasonably consistent magnitudes. This list is not ideal though: in some areas of the sky it has been exhausted, and it does not include galaxies in the Southern Hemisphere. Therefore, defining new lists of galaxies to observe is becoming increasingly important.

An alternative to the magnitude-limited survey is the objective-prism survey. Here the original observations are wide-field photographs taken with Schmidt telescopes that have thin prisms placed in the light path. Very small spectra that can be used to detect active galaxies with emission lines are produced. Unlike faint absorption lines, emission lines are brighter than the continuum and relatively easy to see. These lines arise from the interstellar gas within the galaxies and are the result of a variety of energetic processes. Surveys based on emission lines miss much detail of structure, but they do offer an alternative to the unknown biases of magnitude-limited surveys, and they have already detected a number of galaxies in the Bootes Void, one of the most expansive voids discovered to date.

Before superclusters were well observed, most astronomers assumed superclusters would be nearly perfectly spherical with a core/halo structure. Gerard de Vaucouleurs' studies of the Local Supercluster in the 1950s suggested that the Virgo Cluster was surrounded by a roughly uniform assembly of small galaxy groups, although there

The Perseus Supercluster

Out of a sea of galaxies the Perseus Supercluster emerges as a gently curving arc of galaxies running continuously through Perseus and Pegasus. This map was generated by plotting galaxies between photographic magnitudes 14 and 15 in the region of sky between 21 and 6 hours right ascension and −15° and +90° degrees declination. Each cross indicates the position of a galaxy. Map by Stephen A. Gregory.

was a decided elongation to the system. It quickly became apparent with the observations of external superclusters that superclusters almost always have a filamentary structure that stretches across millions of light-years of space. Some systems suggest a sheetlike structure with one very small dimension. Instead of describing superclusters as a spherical cloud, like a swarm of gnats, a better description is a string of different-sized pearls. The galaxy-rich Perseus Supercluster traces out a gently curving arc across at least 90° of sky.

All rich galaxy clusters appear to lie in superclusters, and the typical lengths of these clusters are hundreds of millions of light-years — comparable to the distance between the Local Group and the Coma Cluster. At the University of New Mexico David Batuski and Jack Burns have found one supercluster in the Perseus/Pisces region that may be 1 billion light-years in length.

Richard Fisher and R. Brent Tully have examined the Local Supercluster in great detail. A filament can be seen running through the general disk; these two parts account for about 60 percent of all member galaxies. The halo contains the remaining 40 percent of galaxies, but these galaxies are so concentrated into groups that the halo is about 95 percent empty. Tully believes all of the nearby superclusters form a very large structure with a length of about 1 billion light-years. Is this a third-order cluster, in effect a cluster of superclusters?

Voids Not Completely Empty

Unlike the strings or sheets of superclusters, voids often appear spherical. Only one or two voids have reasonably well-defined borders to test for shape, but voids — whether you plot them in right ascension and declination or in three-dimensional space — uniformly give the impression of being nearly round. The sizes of voids are about the same as those of superclusters, but for voids this characteristic distance measurement represents the *diameter* of a sphere rather than the *length* of a string. Obviously a sphere occupies much more volume than a string of the same scale length. Therefore, the empty volume of the universe is vastly greater than the occupied regions.

The first voids discovered had diameters of 60 million to 120 million light-years. In 1981 Robert Kirshner, Augustus Oemler, Jr., and Paul Schechter discovered a void in the direction of the constellation Bootes that was about 250 million light-years across.

The Bootes Void has certainly generated more interest than any other. Its vast size makes it a very strong test of galaxy cluster and supercluster formation theories. In some models of the universe the distribution of galaxies gives a biased view of the true structure of bright matter because massive galaxies form only in the densest regions of space. A more accurate view of large-scale structures might be obtained by tracing the distribution of dwarf galaxies. But as mentioned, these galaxies are too faint to be detected in Earth-bound telescopes, except for those in our galactic neighborhood. Hence, determining the true large-scale structure of the universe is complicated by the need to know whether dwarf galaxies exist in voids or not.

Recent observations in the Bootes region have answered this question, at least with respect to that particular void. Joseph Moody, William Tifft, Robert Kirshner, Gordon MacAlpine, Stephen Gregory, D. Wiestrop, and Ronald Downes have shown that at least ten galaxies lie within the void boundaries. Some theories had predicted that there might be dwarf galaxies in voids, but the newly discovered objects are not dwarfs: they are about as luminous as our own Milky Way Galaxy. The void galaxies do have one peculiarity. They were discovered by an objective prism survey, and thus all have emission line spectra. Because only about 5 percent of all galaxies are energetic enough to exhibit emission lines, it is unusual for all ten members of a particular sample volume to be so active.

What is this fact telling us? The answer is only speculation at the moment, but these galaxies could be much younger than the 10 billion-year-old galaxies we see in clusters and are only now "turning on." Perhaps conditions in the void did not completely rule out galaxy formation but only delayed it.

One other void has been studied as well as the Bootes Void. The Coma Void is smaller but considerably closer to us; therefore, we can search it to far fainter limits than more distant regions. However, a joint University of Arizona/University of New Mexico survey has found no galaxies within the Coma Void, and this study has searched portions of the void much fainter than in the Bootes studies. One tentative explanation for the seeming disparity of one void appearing quite empty while another is not, is that the Bootes Void represents a different class of void that is larger but not as empty. Another possibility is that the differences simply arise from statistical uncertainty. (Statistical uncertainty refers to the luck factor involved in cosmic searches. In this case the probability of finding a galaxy in one void is the same as in all voids. But by chance astronomers sometimes find galaxies and by chance sometimes they don't.)

One other aspect of the Coma Void is quite important. Valerie de Lapparent, John Huchra, and Margaret Geller have suggested that voids are like "bubbles." This distinction implies that the borders of voids are unbroken and, as stated in one theory, might be a natural consequence of explosions of stars in young galaxies. However, J. Richard Gott, Adrian Melott, and M. Dickenson have shown this is probably not the case in general, and the detailed Coma Void studies have shown that this void in particular has a quite open, or netlike, border. Based on these observations, it seems more likely that the structure of voids is "spongelike" rather than bubblelike, with one void merging into another.

This last point raises new possibilities. Are all voids interconnected? Batuski and Burns have found evidence that even the great Bootes Void is just part of a much larger system based on their detailed Coma and Bootes redshift surveys. Voids, in fact, might not be considered as separate structures but as integral parts of the same process that formed the galaxies.

It seems that as we look to larger volumes of space we keep finding larger structures. Will we ever find an end to the tangle of superclusters and actually be able to say we are observing a "fair sample" of the universe? If we do, will we have finally reached a scale at which the survey is greater than the scale of the supercluster filaments, and the universe will appear uniform everywhere and in all directions.

In part four Adrian Melott describes how computer models help astronomers in their attempts to fathom the structure and evolution of the universe.

Stephen A. Gregory is an associate professor at the University of New Mexico. His research specialty is the large-scale structure of the universe.

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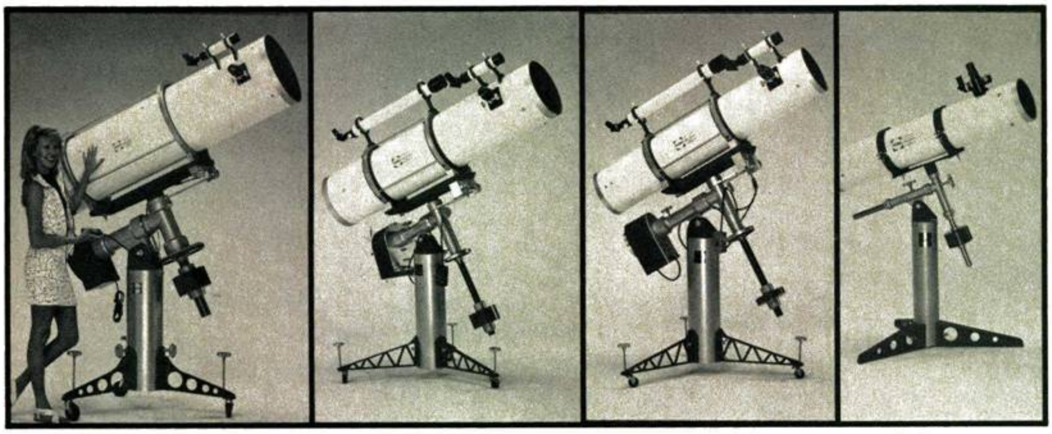

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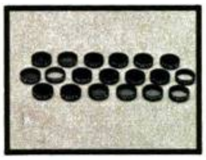

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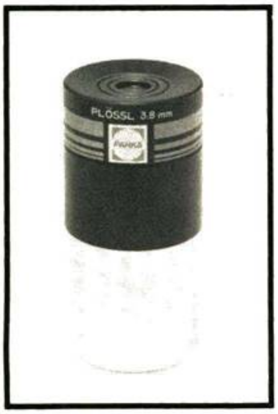

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by Robert Burnham, Jr.

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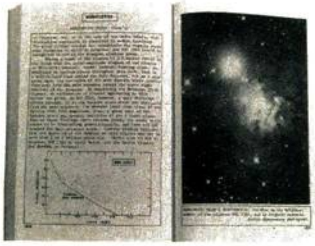
Robert Burnham, Jr.



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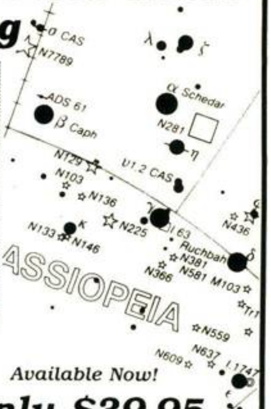

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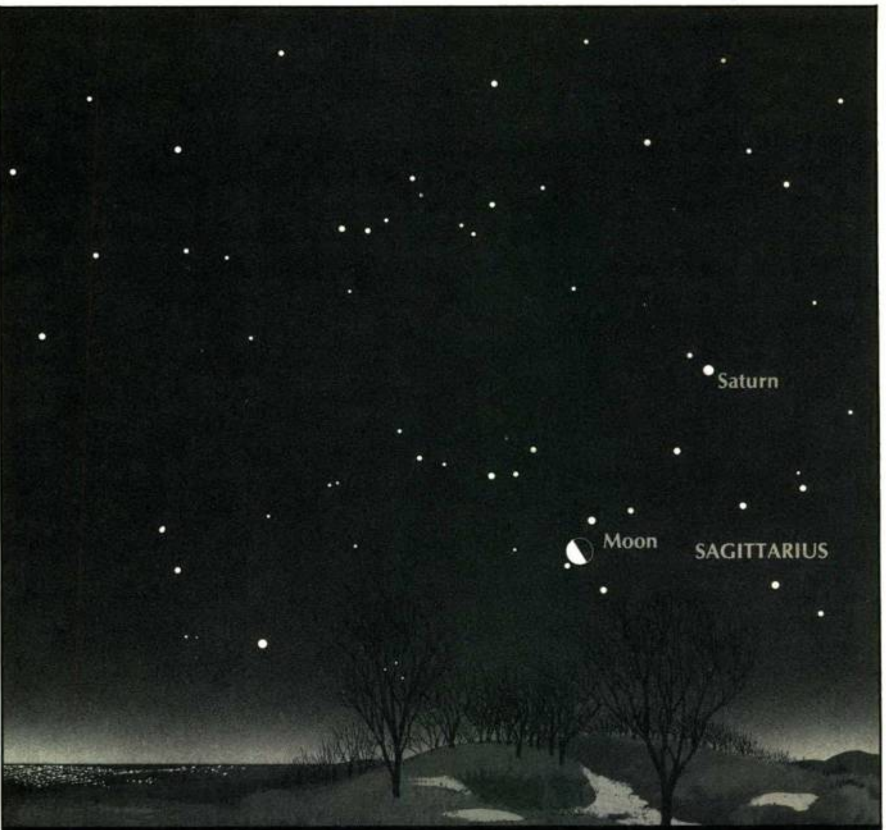
Venus, the "Evening Star"

by Robert Burnham



Looking southeast, April 9, 4 a.m.

The Wanderers

After sunset in early April two "stars" emerge from the deepening blue of evening before any others. The brighter of the two, **Venus**, floats high in the west and is unmistakable at −4.4 magnitude. The other, lying below Venus at less than half Venus' elevation, is **Jupiter**. Venus remains visible until June, but Jupiter's stay in the evening sky lasts only until mid-April.

Venus is moving eastward through the background stars of Taurus, where it passes about 2° south of the Pleiades on the 3rd. Use binoculars for a super view of this bright planet and cluster together in the same field. (April 3 is also the date Venus is farthest from the Sun and highest in the sky.) On the 15th, Venus overtakes Aldebaran, passing a generous 10° north of the star. Venus sets about four hours after sundown.

Some clear, moonless night, wait until the sky is fully dark and see if you can perceive the shadow Venus casts. You'll need a white surface that faces Venus and is shielded from all stray light. Place your hand about six inches in front of the surface and slowly move it back and forth. Can you see the shadow move? It's easy to spot once you've seen it, but any local light falling on the surface destroys the effect.

Jupiter is winding up its yearly apparition as it sinks steadily lower each evening. Although it shines at magnitude −2.0 and is some 12° high (forty-five minutes after sunset on April 1), Jupiter is swallowed up in the glow of twilight soon after the middle of April.

At the very end of April **Mercury** appears low in the northwest after sunset, but its elevation on the 30th is only 3°. Shining reddish white at magnitude −1.4, it resembles a steadily shining star low in the twilight. However unpromising, this is the start of the year's best viewing opportunity for Mercury. Mercury will be much higher and easier to see by the middle of May.

About an hour after Venus sets, **Saturn** rises in the southeast, followed by **Mars** about two hours later. Both planets, though, can be seen more easily during the hour before sunrise. Saturn at that time lies due south about 30° above the horizon and gleams ivory-white at 0.4 magnitude. Saturn is surrounded by the stars of a summer evening — Ophiuchus, Scorpius, and Sagittarius. As bright as Saturn, orange-white Mars lies to Saturn's lower left among the stars of Capricornus rising in the southeast.

The April **Lyrid meteor shower** is a relatively sparse display of medium-swift meteors (48 kilometers per second), and the numbers of meteors can vary greatly from year to year. This year you'll see the most meteors in the predawn hours of the 21st and 22nd. Although the radiant (near the Lyra-Hercules border) rises around 8:30 p.m. daylight time, the First Quarter Moon hangs in the sky until midnight or later. After it sets, you should be able to see about ten to fifteen Lyrids an hour at a site free from outdoor lights.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

The Starry Sky

When the bright winter stars depart for the year, the new sky looks *dark*. Even city dwellers can enjoy winter's constellations from the backyard, but the dimmer figures of spring vanish in the sky glow. For the first two weeks of April the Moon will light up the evenings, but if you plan a sky-watching jaunt out of the city for sometime after the 15th, you can learn the stars of spring from the dark countryside, unhindered by lights.

Facing west, you'll see familiar **Orion** the Hunter hiding in the trees along the horizon. Bright yellowy Capella stands to Orion's upper right in **Auriga** the Charioteer, a pentagon soon to sink into the haze. Above Orion stand the **Gemini** twins, brothers linked arm-in-arm in an upright rectangle headed by their bright namesake stars Castor and Pollux. Left of Orion, the Greater Dog **Canis Major** follows Orion with brilliant Sirius leading the way. Above Sirius is Procyon, the only

Opposite page: As the Sun nears the horizon, its rays travel through greater lengths of the atmosphere, weakening the rays so much that the Sun appears red and can be looked at directly. The disk appears flattened because rays from the lower edge of the Sun are bent in the Earth's atmosphere more than rays from the top of the Sun. Consequently, light from the Sun's lower edge seems to be coming from a higher point in the sky. Photo by David Rights, taken with a 1000mm telephoto at f/16 on Kodachrome 25 film and a 1-1/4-second exposure.

April Night Sky

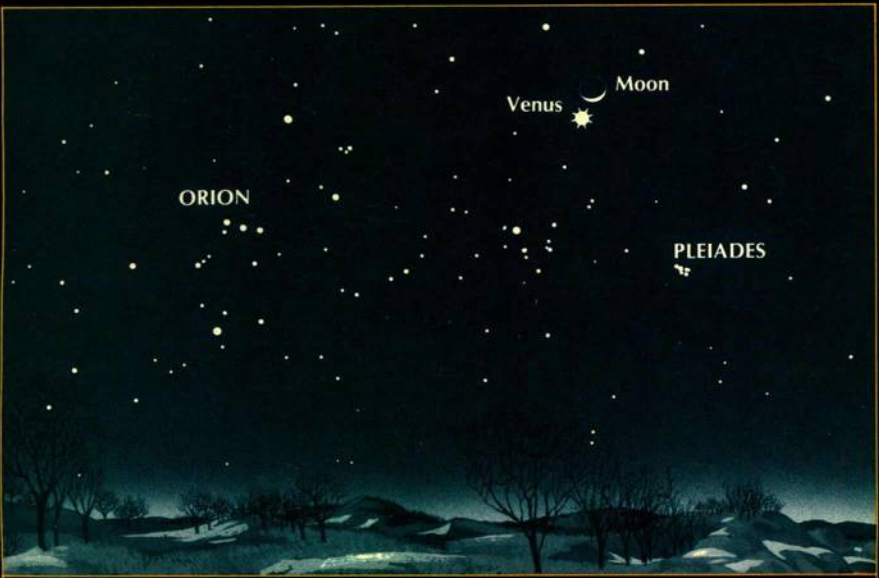
Full Moon
April 2
4:21 a.m. EST

Last Quarter
April 9
3:21 p.m. EDT

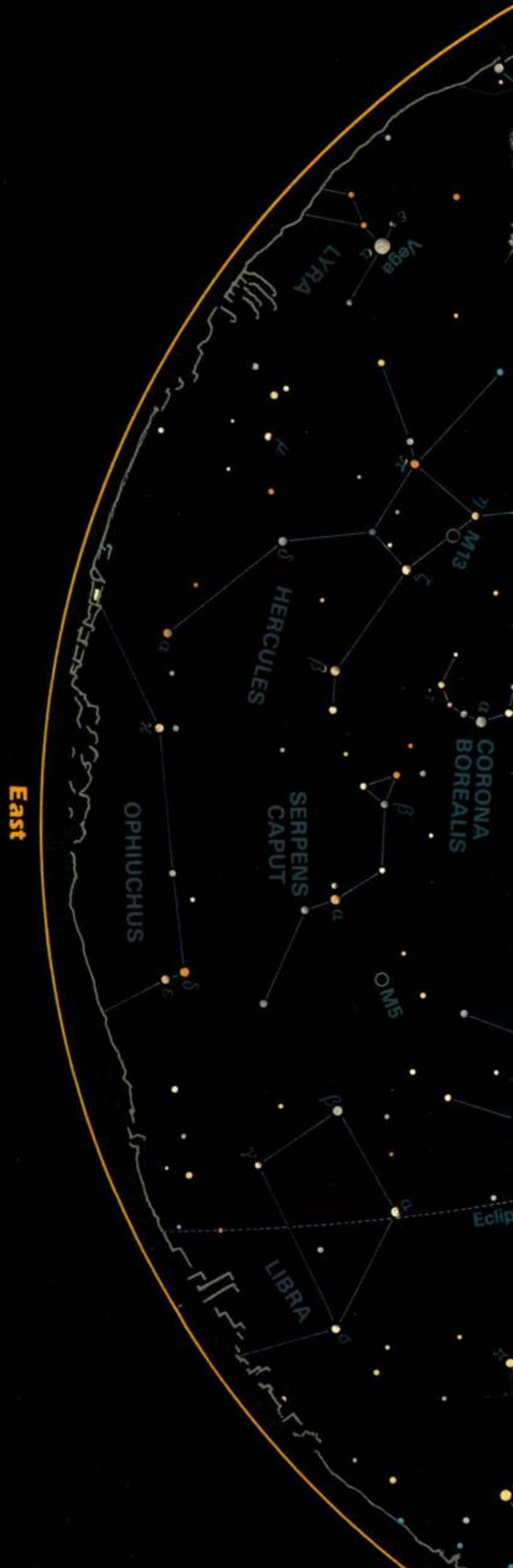
New Moon
April 16
8 a.m. EDT

First Quarter
April 23
6:32 p.m. EDT

2nd	Full Moon occurs at 4:21 a.m. EST in Virgo.
3rd	The Moon passes south of 1st-magnitude Spica in Virgo, covering the star for viewers in parts of the Southern Hemisphere. Venus is at greatest eastern elongation (and best visibility) in the evening sky only a few degrees south of the Pleiades.
9th	The Moon is at Last Quarter at 3:21 p.m. EDT in Sagittarius.
13th	The Moon is closest to Earth at 6:49 p.m. EDT: 226,373 miles (364,311 kilometers).
15th	Venus lies about 10° north of 1st-magnitude Aldebaran this evening. At about 10 p.m. the Milky Way lies around the horizon, lost in the encircling haze. We are looking up out of the northern side of our Galaxy toward the galactic pole, which is located in Coma Berenices and marked "NGP" on the star map.
16th	New Moon occurs at 8 a.m. EDT in Pisces.
18th	Tonight the crescent Moon lies near the Pleiades.
19th	The Moon is very close to Venus this evening, covering the planet for viewers in the arctic regions and Iceland. (See the diagram below.)
21st	The predawn hours of today and tomorrow offer your best chances of seeing members of the Lyrid meteor shower (see text).
23rd	First Quarter Moon is at 6:32 p.m. EDT in Cancer; it lies near the Beehive Cluster (M44 on the star map).
25th	The Moon is farthest from Earth at 2:34 p.m. EDT: 251,351 miles (404,510 kilometers).

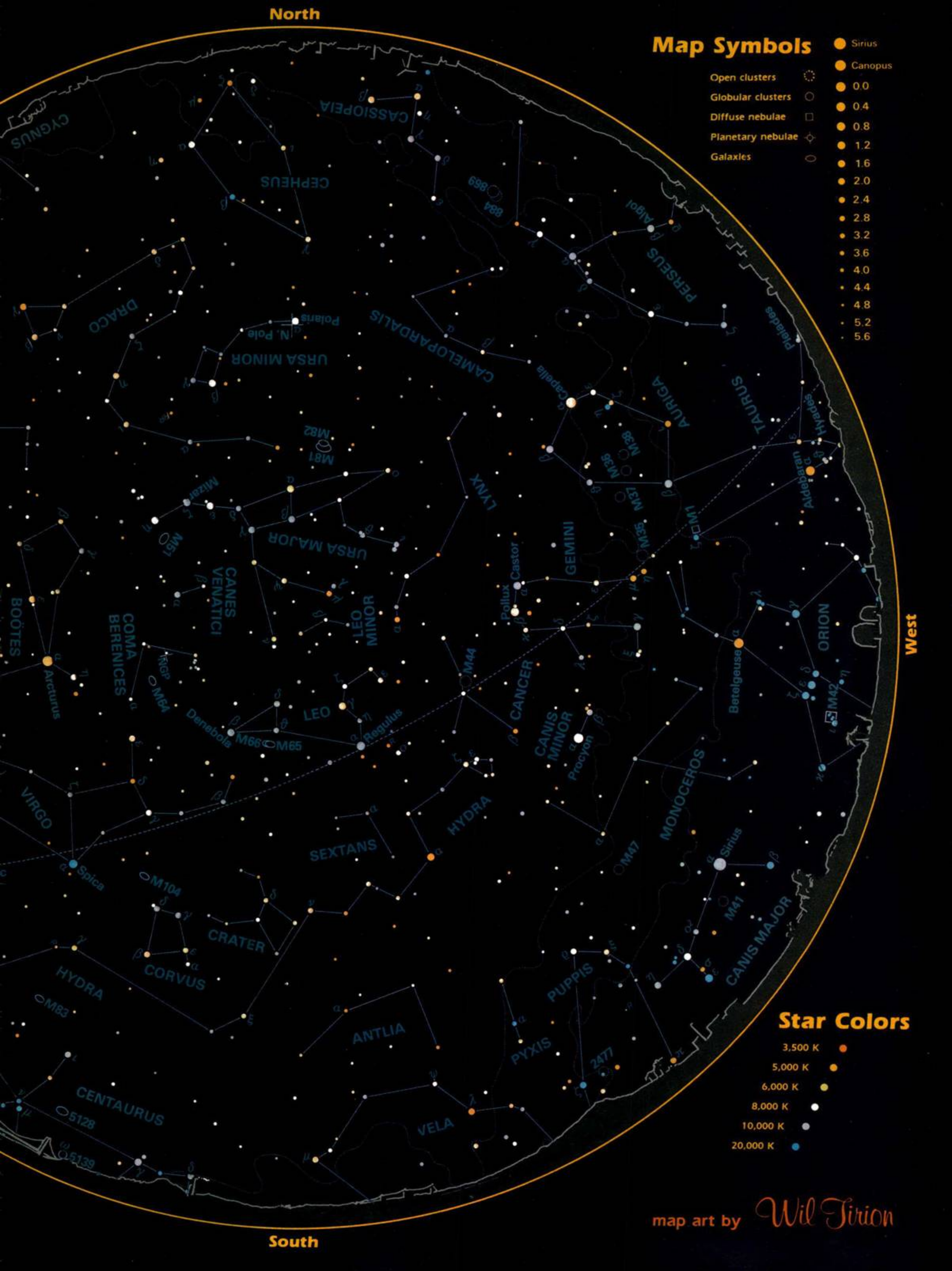


Looking southwest, April 19, evening twilight



The
Star Dome
shows how the
sky looks at:

9:30 p.m. standard time on April 1
9:30 p.m. daylight time on April 15
8:30 p.m. daylight time on April 30


North
Map Symbols
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Sirius
Canopus
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CYGNUS
CASSIOPEIA
CEPHEUS
869
884
Algol
PERSEUS
DRACO
Polaris
N. Pole
URSA MINOR
CAMELOPARDALIS
Pleiades
Capella
AURIGA
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M51
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GEMINI
BOÖTES
COMA BERENICES
NGP
M64
Arcturus
M44
CANCER
Betelgeuse
ORION
M42
West
Denebola
M66
M65
LEO
Regulus
CANIS MINOR
Procyon
MONOCEROS
VIRGO
HYDRA
SEXTANS
M47
Sirius
Spica
M104
M41
CANIS MAJOR
CRATER
CORVUS
HYDRA
M83
PUPPIS
ANTLIA
PYXIS
2477
CENTAURUS
5128
VELA
5139
Star Colors
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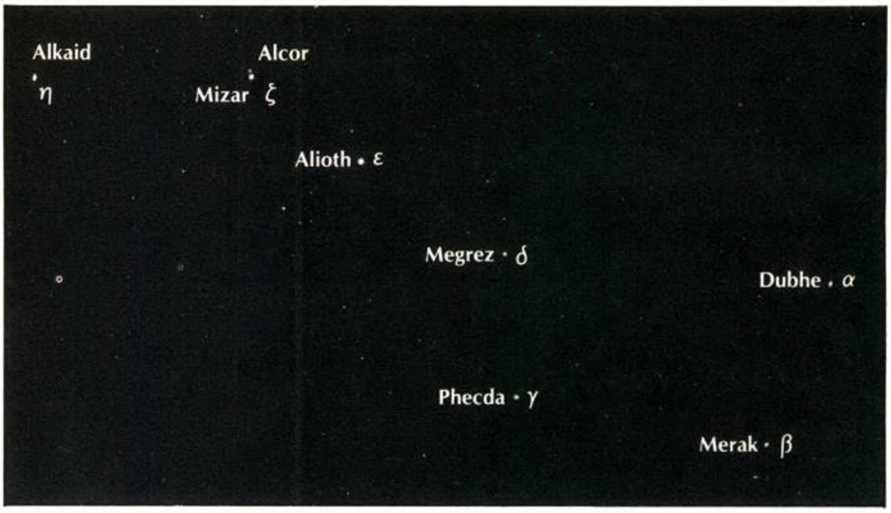
6,000 K
8,000 K
10,000 K
20,000 K
South

map art by Wil Tirion



The Big Dipper is the bright grouping within the constellation Ursa Major. Photo by Scott Patterson, who used a 55mm lens at f/1.8, Tri-X film pushed to ISO 800, and an 18-second exposure.

bright star in the Lesser Dog **Canis Minor**.

A large figure winds across the dark expanse in the south: **Hydra** the Water Snake, a fearsome mythological monster slain by Hercules. Hydra's head is a small oblong of six stars to the upper left of Procyon. From the head the snake's body wiggles east in a crooked line of 3rd- and 4th-magnitude stars, passing the Cup **Crater** and the more prominent Crow **Corvus** on the way. Can you find all of Hydra? Carefully check the map against the sky and make sure you don't zig where Hydra zags!

Above the back of Hydra the wide reclining figure of **Leo** the Lion has 1st-magnitude Regulus caught in its forepaws. (In the sky the distance from Regulus to Denebola in Leo's tail may appear greater than the map indicates.)

Now turn and face due north. Polaris the pole star is the bright tip of the tail of the Lesser Bear **Ursa Minor**. The rest of the figure lies to the upper right of Polaris. The Greater Bear **Ursa Major** — its seven brightest stars make up our famed Big Dipper — lies high above Polaris as if to pour water on Polaris. The she-bear's nose points to the left across **Lynx** to Capella in Auriga. The Bear's feet lie overhead and reach toward Leo, but it's easy to confuse them with inconspicuous **Leo Minor**, so look carefully.

None of us would choose to get between a she-bear and her cub, but **Draco** the Dragon is unafraid: its tail curls partway around Polaris and divides the Greater Bear from the Lesser. As with Hydra, tracing Draco takes care.

The Bear's long tail (the Dipper's handle) curves toward the east in an arc that points down toward a bright yellow-orange star called Arcturus, part of **Bootes** the Herdsman. It's easy to remember this star's name because you "follow the arc to Arcturus." Bootes' shape usually reminds people of a kite or one of those old-fashioned belly-warmer neckties.

Between Arcturus and Denebola in Leo lies dim **Coma Berenices** or Berenice's Hair. Under dark skies a large, faint star cluster can be seen by the naked eye in this region as a hazy patch that breaks up into individual stars in binoculars. When Coma passes overhead, the Milky Way lies all around the horizon. We are then looking directly out of our spiral arm toward a huge (but telescopic) cluster of galaxies 65 million light-years away, the nearest intergalactic neighbors to the Milky Way's own Local Group.

Below Bootes is a small semicircle of stars. Known as **Corona Borealis** the Northern Crown, this figure actually *looks* like a diadem. On Corona's left **Hercules** is rising out of the haze and will be more prominent later tonight or this time of night next month.

To the right of Arcturus a blue-white star stands out above the southeast horizon near the tail of Hydra. Spica is an ear of wheat held in the hand of **Virgo** the Maiden. (In Roman mythology Virgo was Ceres, the goddess of grain.) To remember the star's name, simply complete the mnemonic: after arcing to Arcturus, you "speed on to Spica."

Skylore

Like many star names, those of the bears derive from Arabic and often identify the part of the ursine figure they represent. Alpha (α) at the lip of the Dipper's bowl is named Dubhe (DUBB-hee), which is short for *al-thahr al-dubb al-akhbar*, "the back of the greater bear." Beta (β) is called Merak (MEH-rak), originally *al-merakk*, "the loins." Together Alpha and Beta are known as the pointers, because a line from Merak to Dubhe extended a little more than five times will reach almost exactly to Polaris, the pole star.

Gamma (γ) in our figuration helps define the bottom of the Dipper, but its name, Phecda (FEK-dah), comes from the Arabic *al-fahdh* and means "the thigh." Delta (δ) is the dimmest star in the Dipper but appears more prominent because it completes the bowl. Its name is Megrez (MEH-grez) and is relatively uncorrupted, the original being *al-maghrez*, which means "the root of the tail."

Proceding down the Dipper's handle, we meet Epsilon (ε), called Alioth (ALLEY-oath), a name that frankly doesn't fit anything in our mythological picture. Its origin is uncertain, but the closest Arabic is *alyat*, meaning the fat tail of a sheep!

The Dipper's handle makes a bend at the next star, Zeta (ζ), called Mizar (MY-zar). Originally this star carried the name Mirak (which Beta now has), but Joseph Scaliger named it Mizar in the sixteenth century and the name stuck. Mizar, however, means "girdle" or "waist-cloth" and makes little sense given the star's position in the figure.

Alcor is the name of the little star next to Mizar, which is supposed to be used as a test of eyesight. In fact, Alcor isn't very hard to see, although its name derives from the Persian for "the friendless one" and a similar Arabic word means "the faint one." Together with Mizar, the pair is sometimes called the Horse and Rider.

The last star in the handle of the Dipper is Eta (η), called Alkaid (al-KAYD) or Benetnasch (BENNETT-nash). Neither name fits the bear mythology; instead both refer to an alternate tradition in which the Dipper represents a funeral bier with mourners. Thus Alkaid comes from the Arabic *al-kaid al-banat al-na'ash*, "the chief of the daughters of the bier" (i.e., the first mourner) and the derivation of Benetnasch is obvious.

Compared to Ursa Major, the Lesser Bear is poor in named stars. Alpha is called Polaris, a name that will begin to seem odd in a couple of centuries as precession robs Polaris of polar position. Beta is called Kochab (COACH-ab), derived from the Arabic for "the star of the north," a title it formerly shared with Polaris. Gamma appears as Pherkad (FAIR-kad), a corruption of the Arabic for "the dim one of the two calves."

While most mythologies have identified these two figures as bears, it is a mystery why so many should do so. Next month we'll take a look at some of these myths.

Opposite page, top: Brian Skiff of Lowell Observatory in Flagstaff, Arizona, photographed a three-order corona by blocking the Sun's bright disk with a convenient rooftop. The coronal pattern is a diffraction effect caused by sunlight scattering off water droplets in the atmosphere. Skiff used a 200mm lens and Kodachrome 64 film. (The "star" in the corona is an emulsion defect.)

Opposite page, bottom: Saturn, Jupiter, and Venus glowed through a deepening twilight evening in August 1981 over Chews Ridge, California. Photo by Donna Gray.

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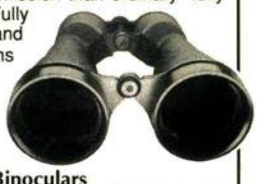

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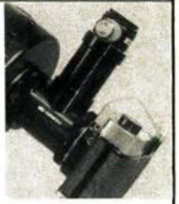

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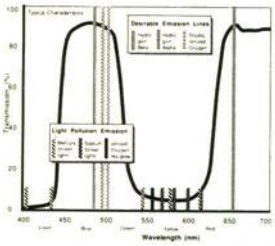

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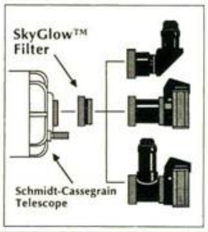

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Photography
in
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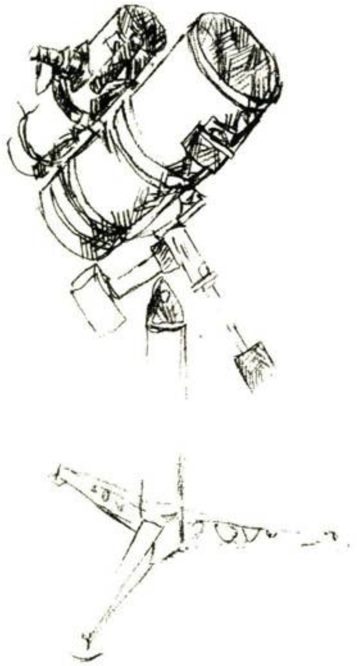
Prime-Focus Photography with Small Telescopes

by Andrew Packer



Small telescopes are wonderful. They are inexpensive, highly portable, and offer observers pleasing views of many objects in the sky. However, many owners of small telescopes don't realize their instruments are capable of producing high-quality photographs of the sky. A small telescope, whether it is a 4-inch f/6 or a 6-inch f/8 Newtonian, a 3-inch f/12 refractor, or a 300mm telephoto lens (which, after all, is a small telescope) can give excellent results with color or black-and-white films.

Photographing objects at the prime focus of such an instrument will yield pleasing close-up views of the Moon, nebulae, and galaxies. All that's required is a telescope, the right mounting, a drive corrector, a guidescope, a camera, film, a thorough knowledge of what to do, and a little persistence. I've used a 4-inch telescope on a sturdy equatorial mount to make photographs of celestial objects for several years now and find this type of photography a satisfying challenge.

A Small Scope Setup

The first requirement for prime-focus photography is solid, reliable equipment. You'll also need to choose equipment that works together as a system. The mount is the most important part of any astrophotographic setup. If you have a wonderful telescope with great optics and it's placed on a shaky, inadequate mount, you'll never be able to get photos you're happy with. You can never get a mount that's too sturdy. Even if you get a mount that's too massive for the telescope you have, you'll be ready if you decide to get a larger telescope in the future.

The basic type of mount is the equatorial. This mount makes it possible to track the stars in a single motion, which allows you to record sharply defined stars by guiding the telescope with a high-magnification eyepiece. An equatorial mount with a clock drive, whether it's a German equatorial or a fork equatorial, is essential for photographing faint objects.

Along with an equatorial mount and your telescope tube, you'll need a drive corrector. This device is a small "black box" of electronic circuitry that allows you to make small changes in the drive motor's speed during an exposure, thus maintaining accurately guided photos.

You'll also need a separate guidescope or an off-axis guider. Either will allow you to watch a star at high magnification and make corrections with the drive corrector if the star moves away from a set of illuminated cross hairs in your guiding eyepiece. (For more information on prime-focus setups, see Equipment Atlas on page 62.)

Another type of mount, the altazimuth, moves in up/down and left/right axes only. An altazimuth mount cannot track the stars in a single sweeping motion and therefore makes astrophotography difficult if not exasperating. Such a mount will essentially confine you to bright objects like the Moon, Sun, and planets.

Polar Alignment

Before you can take a guided photograph with your telescope, you must polar align the mounting. This involves precisely aligning the polar axis of the telescope with the north celestial pole, the point in the sky around which stars appear to rotate. This will enable you to track the stars and record stars as dots rather than as blurred trails. This step is important enough that you should learn how to do it very well, or you will invariably have to make enormous corrections while guiding and will end up with less than spectacular results.

The bright star Polaris (Alpha [α] Ursae Minoris) lies just 1° away from the north celestial pole, but aligning your telescope on Polaris won't prove accurate enough during a long exposure. Many mounts have built-in pole finders consisting of a small sighting tube that allows you to spot the right place in the sky to align the telescope with. If your mount has a pole finder, aligning the telescope should be relatively simple. If your mount does not have such a device, you'll have to align your telescope by setting the declination axis of the telescope at 90°, making sure the pedestal or tripod is level, and using a chart of the pole area to find the exact spot at which to aim your telescope. (For detailed instructions, see "How to Use a Polefinder" by Paul J. Burke, Equipment Atlas, May 1985 and "Easy Steps to Perfect Polar Alignment" by Robert Burnham, Equipment Atlas, August 1982.)

Guidescopes and Guiding

During a long-exposure photo your guidescope or off-axis guider is your best friend. It allows you to track precisely on the stars by keeping a bright star centered on an illuminated cross hair in an eyepiece made especially for astrophotography. You do this by placing an illuminated reticle eyepiece in the guidescope or off-axis guider, centering a bright star on the glowing cross hairs in the eyepiece, and using the drive corrector to make small corrections in the drive to keep the star perfectly centered in the cross hairs. By doing so, you'll make sure you have pinpoint star images in every photo you take.

Using a separate guidescope has its

Opposite page: Small telescopes are capable of producing impressive prime-focus results. This photo of the Lagoon and Trifid nebulae in Sagittarius was made with a 4.25-inch f/5.6 Newtonian reflector, Fujichrome 100 film, and a 60-minute exposure. Photo by Brad Wallis.

Small telescopes have focal ratios fast enough to record very faint objects in relatively short exposures. This photograph of the Horsehead Nebula in Orion is a 20-minute exposure on 3M-1000 film, made with a 5.5-inch f/3.6 Schmidt-Newtonian. Photo by Hal Jandorf.

advantages and disadvantages. Mounted on top of the telescope piggyback-style, the guidescope allows you to move the guidescope by a few degrees to find a suitably bright star on which to guide. This is very handy, but the separate guidescope also offers a potential problem called flexure. If the guidescope moves — or even flexes under its own weight — relative to the main telescope during an exposure, you'll get trailed star images. This can be avoided or at least minimized if you make sure all of the bolts that hold the guidescope in place are firmly tightened, thus prohibiting movement during an exposure.

An off-axis guider consists of a tube with a small mirror inside that deflects light from the optical path of the telescope to an eyepiece mounted at the back end of the telescope. These guiding devices work well and don't cause flexure problems, but they limit the distance you can move to find a guide star: it is often difficult to find a bright enough guide star within the field of the object you're photographing.

When it comes to guiding, small telescopes offer one extremely important advantage over large ones. Because small scopes have relatively short focal lengths, the precision with which you must keep the guide star centered is relatively low. In other words, if the star drifts by two or three star-diameters for a second or two before you recenter it on the cross hairs, your photograph will not show it. With a large telescope and its correspondingly longer focal length, letting a star drift for one or two seconds can ruin a photograph, because the star is recorded on film as a trail rather than a dot.

The key to minimizing guiding difficulties is using high magnification with the guidescope. The higher the guidescope magnification, the smaller the corrections you can make as the guide star moves away from the cross hairs. For a 6-inch f/4 telescope (24 inches focal length), for example, I recommend a guiding magnification of at least 130x. With a longer focal length system, say a 6-inch f/8 telescope (48 inches focal length), use a guiding magnification of about 200x.

Camera Equipment

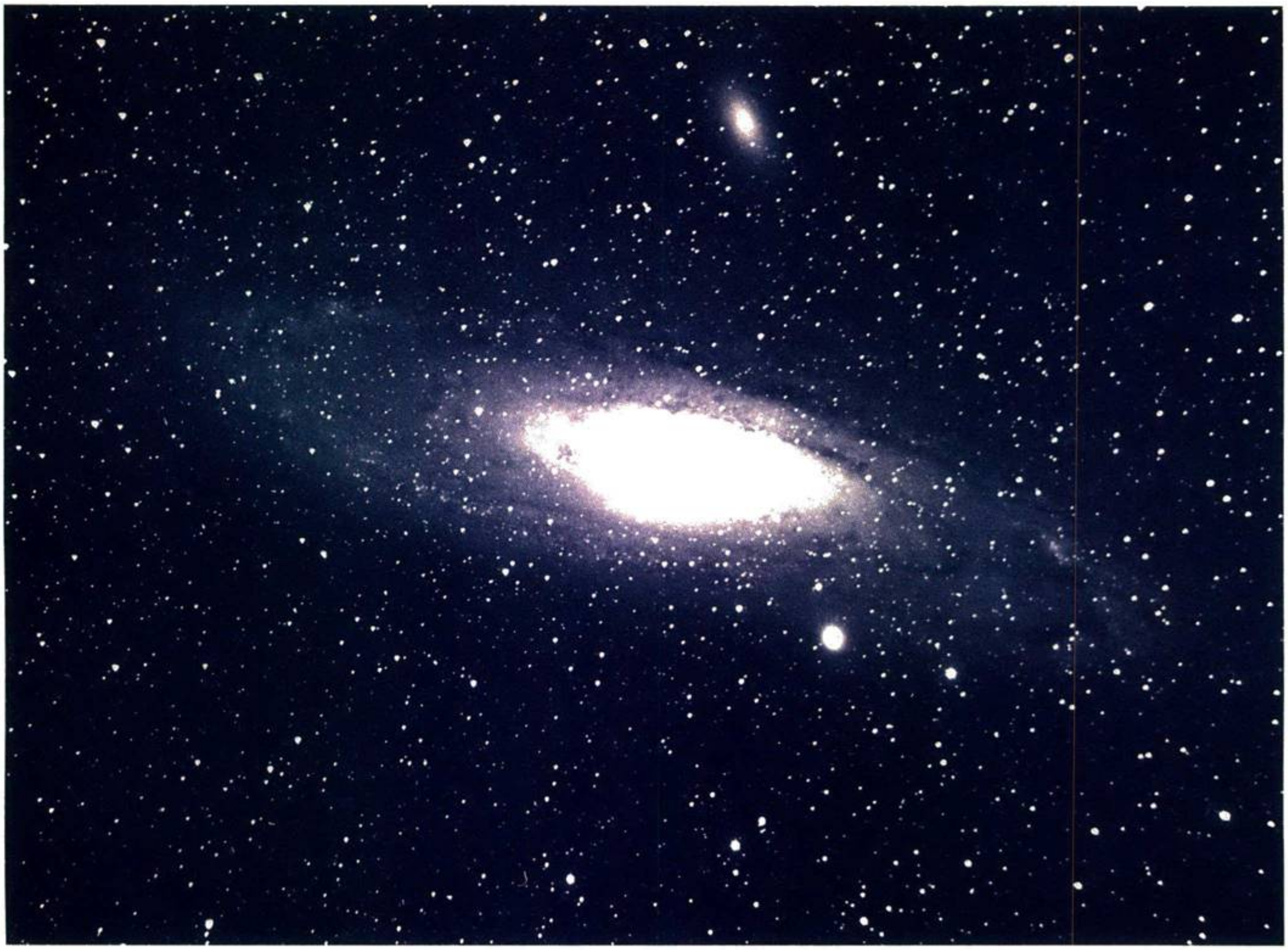
Because it holds the film that becomes the astrophoto, the camera is an important part of the astrophotographic system. What exactly makes an astrocamera? An astrocamera can be as simple as a light-tight box that holds a piece of film at the focus of a lens or mirror. Realistically, however, the least frustrating "box" is a 35mm SLR camera with a clear focusing screen. The clear screen lets you focus sharply on a star, which many of the ground-glass screens don't allow.

Also, make sure any camera you use for astrophotography has a mechanical shutter rather than a shutter operated by batteries. Battery-operated shutters use electricity to stay open. During exposures you may find that such a shutter decides to close when the batteries run out of charge. Even if that doesn't happen, you'll discover you've spent a small fortune on batteries after a season of astrophotography. Neither prospect is a good one.

Another necessity for your camera is a cable release, available from any photo supply store. With the cable release you open the shutter at the beginning of an exposure and close it when you're finished taking the photograph. The device allows you to hold the camera's shutter open for as long as you wish to collect faint light from astronomical subjects.

Choosing a Film

You'll also have to learn which film is best in the camera. Film choice comes down to a matter of experimentation and personal preference. Many films on the market today will produce reasonably satisfactory results with astronomical objects. I suggest you try a few and see which you



Prime-focus photography with small scopes works best on large objects. This photo of the Andromeda Galaxy is a 30-minute exposure on hypersensitized Tech Pan film made with a 5.5-inch f/3.6 Schmidt-Newtonian. Photo by Geoff Chester.

like best. The idea is to capture as much detail in objects as quickly as possible with the least amount of film grain.

As far as black-and-white films go, Kodak's Tri-X is an old standard that is reliable and at ISO 400 pretty fast stuff. The new T-Max 400 is very good, as fast as Tri-X and even finer grained. Much finer grained but also trickier to use, Kodak's Tech Pan 2415 is probably the finest black-and-white film on the market. However, it is intrinsically slow and must be "hypersensitized" (soaked in gas) to make it fast enough for recording faint objects. Several commercial suppliers offer hypersensitized Tech Pan film by the roll, and at least one of them offers a home hypersensitizing kit so you can treat your own films for maximum speed.

Color print films often don't work well for astronomical subjects, because the automated printmaking machines at commercial developers are preset for producing color-balanced prints of normal subjects like people. Therefore, the color balance of astronomical shots often looks terrible. Slide films give better results. Kodak's Ektachrome 400 or 1000 speed slide film, 3M's 1000 speed film, and Fujichrome slide films all give good results. Try several and choose the one you're most pleased with.

Objects for Small Telescopes

Small telescopes record certain types of objects better than others, so you might want to concentrate on these objects to get the most impressive results. The best objects for small scopes are those with a large angular size, like large open clusters and nebulae. Objects like the Beehive Cluster in Cancer and the Pleiades in Taurus make excellent small scope targets, while small objects like the Ring Nebula in Lyra and most small galaxies won't look good because they'll appear tiny on the negatives.

Open clusters appear especially good in color slides, which show the different individual colors of the stars. You can record the Wild Duck Cluster (M11) in a 5- or 10-minute exposure. A 15-minute exposure of the Pleiades shows some of the faint bluish reflection nebulosity surrounding several of its stars. The same exposure records not only the rich cloud of stars in M46 but the planetary nebula NGC 2438 that floats in front of the cluster. Large globular clusters are also good targets, although they require somewhat more diligence. A very carefully guided 20-minute exposure made with a 4-inch scope shows the individual stars in clusters M13 in Hercules, M22 in Sagittarius, M4 in Scorpius, and the great Omega Centauri.

Nebulae are more difficult to photograph, but splendid examples await small scope photography. The California Nebula in Perseus, for example, appears as a long, reddish cloud of light in a 15-minute exposure made under a dark sky. The Orion Nebula, M42, is one of the favorite objects of many seasoned astrophotographers. You can record it with just a 10-minute exposure. The Rosette Nebula in Monoceros offers not only a beautiful wreath-shaped nebula but also a bright cluster embedded within, all visible in a 15-minute exposure. Many other nebulae are just as impressive.

Regardless of your particular interest, astrophotography with a small telescope can yield impressive results with relatively little effort. After you assemble the right equipment, choose a few films, and take the initiative to get out under the stars, you'll be able to start collecting your very own images of the sky.

Andrew Packer is a student at the University of St. Andrews in Scotland. He is an active astrophotographer and a member of the Cotswold Astronomical Society, a group of astronomers specializing in astrophotography.

Tools for Prime-Focus Photography

Astronomers are lucky. An amateur archaeologist can't easily collect original specimens, and it's downright illegal to be an amateur physician. But if you're an amateur astronomer, you can collect your own close-up images of magnificent objects in the universe. Prime-focus photography — taking pictures of the sky through your telescope's optical system — is the method you can use to assemble a personal gallery of galaxies, stars, and nebulae. It's not as difficult as you might think. All you need is patience, perseverance, and the right equipment.

The first piece of equipment you need is, of course, a telescope. Most any telescope will allow you to do some photography. In this article we'll focus on Newtonian reflectors. These are good because they combine a large aperture with a low price. We recommend a 6-inch or 8-inch f/5 Newtonian because it is small enough to be easy to use and large enough to give good results. The small size is an asset because the telescope can capture fairly large sections of the sky in a single exposure. More importantly, this relatively small image scale — compared with longer focus instruments like refractors and Schmidt-Cassegrains — minimizes the amount of critical guiding you'll have to do to record stars as perfect dots.

Another important consideration is that Newtonians are much less expensive than refractors and Schmidt-Cassegrains. A short-focus Newtonian will let you see how much you enjoy astrophotography without spending a fortune to find out. If you become seriously involved with through-the-scope photography, you can always buy a larger, more elaborate model later.

The most crucial piece of equipment for astrophotography is your telescope's mount. A heavy-duty equatorial mount is a must. An equatorial mount consists of a tripod that supports a cradle for the telescope's tube. Too many mounts offered with telescopes are inadequate for supporting the weight of the telescope or are poorly constructed overall. It doesn't matter how good your telescope is if the mount is shaky. Make sure you thoroughly check the quality of any mount you buy to see that the mount is more than adequate to support your telescope's weight. (Many astrophotographers buy a mount specifically made for a telescope larger than the one they have.)

An equatorial mount is specially made for following the stars across the sky. Rather than moving in altitude and azimuth like a gun mount, an equatorial mount has a polar axis parallel to Earth's axis and a declination axis set at right angles to the polar axis. When aligned properly on the north celestial pole, an equatorial mount allows you to follow a star across the sky in one axis. A typical equatorial mount comes with a small motor that drives the telescope at the same rate as the Earth turns, thereby keeping a star or object centered in the telescope's field of view.

However, small variations in the electricity powering the clock drive, atmospheric refraction, imperfect polar alignment, and small errors induced by the gears in the drive motor conspire to shift a star away from perfect tracking.

To correct for these minor "wobbles," use a drive corrector to make small changes in the telescope's drive rate by hand. This device is a small box full of electronics that connects to the drive motor. A typical drive corrector is supplied with a hand-controlled "paddle" that you hold during an exposure. The paddle contains a joystick or buttons that allow you to move the telescope ever so slightly in both right ascension (moving the polar axis) and declination. Thus, if a star you're guiding on begins to drift east-

Equipment for Prime-Focus Astrophotography

Any type of **telescope** will work for prime-focus astrophotography. The most convenient type is a small Newtonian reflector. The portability and short focal lengths of small Newtonians make these telescopes attractive for beginning astrophotographers.

An **equatorial mount** follows the paths of the stars in a single motion, which makes guiding possible during a long exposure.

With a **drive corrector** you can make small corrections in the telescope's tracking to ensure round rather than trailed star images on your negatives.

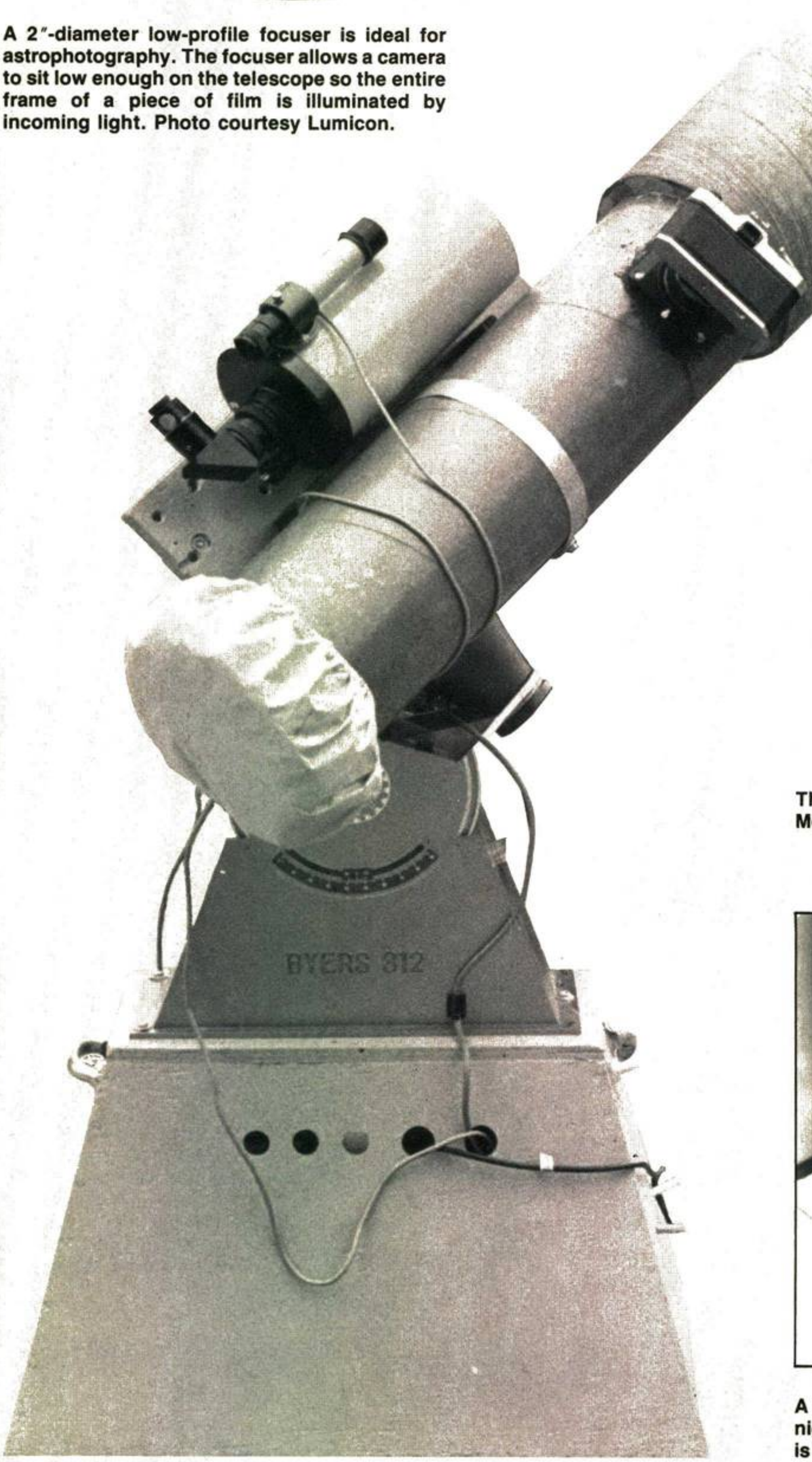
A **guidescope** or **off-axis guider** lets you monitor the telescope's tracking during an exposure.

An **illuminated reticle eyepiece** placed either in the guidescope or off-axis guider provides a means of keeping a star centered in dimly glowing cross hairs, thereby keeping the telescope tracking precisely.

The best type of **camera** for astrophotography is a 35mm single-lens reflex model with a clear focusing screen. This screen allows you to focus sharply on a faint star.

A **cable release** allows you to lock the camera's shutter open to make a long exposure.

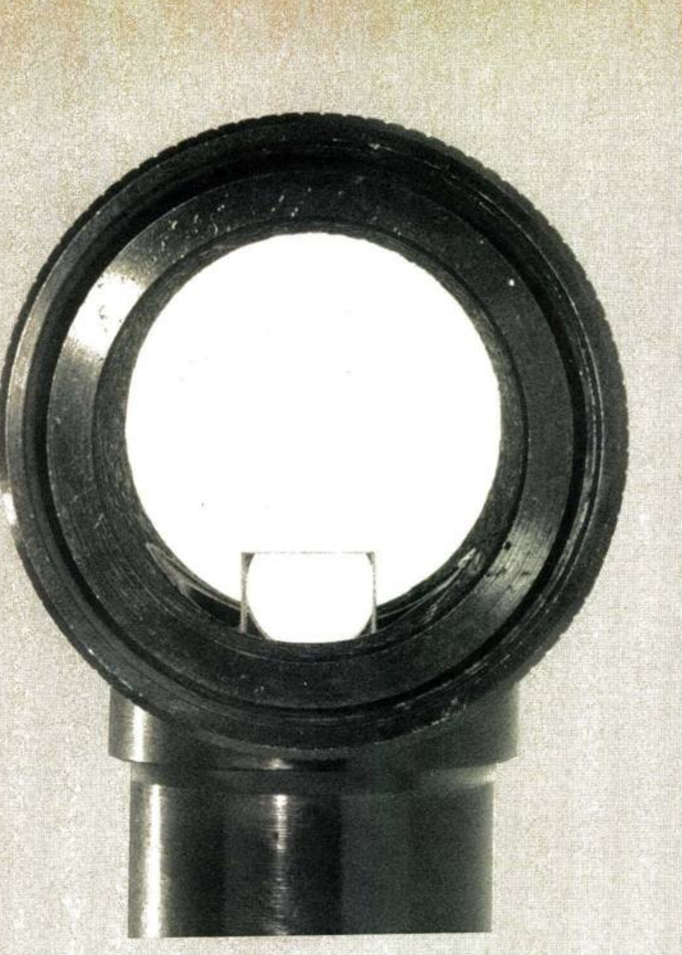
A 2″-diameter low-profile focuser is ideal for astrophotography. The focuser allows a camera to sit low enough on the telescope so the entire frame of a piece of film is illuminated by incoming light. Photo courtesy Lumicon.

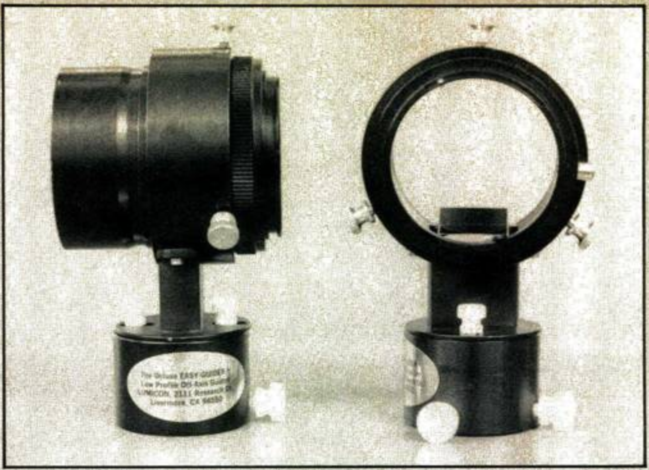


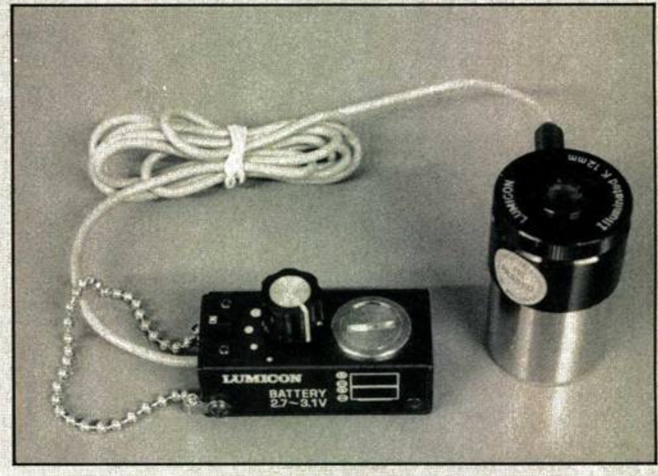
A complete astrophotographic rig. The 6-inch telescope sits on a heavy-duty Byers 812 equatorial mount equipped with a drive corrector. Photo by Richard Berry.

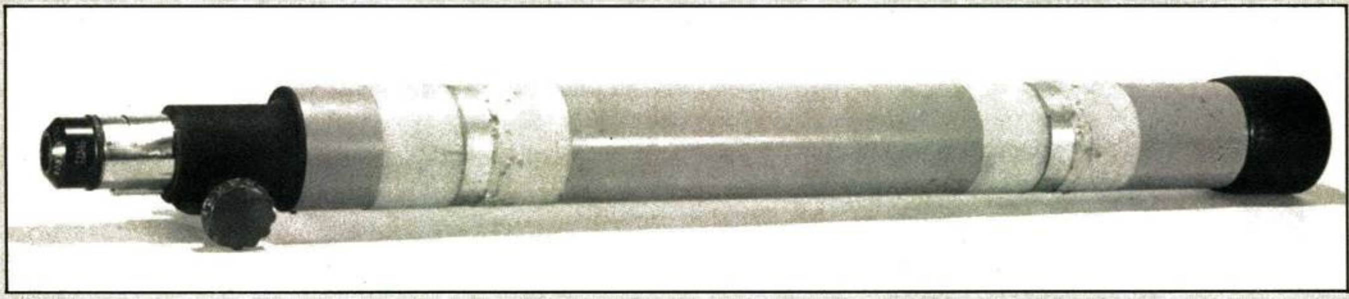
The Helicon low-profile focuser, made by Kevin Medlock, Inc., holds 2-1/2″ and 2″ accessories.

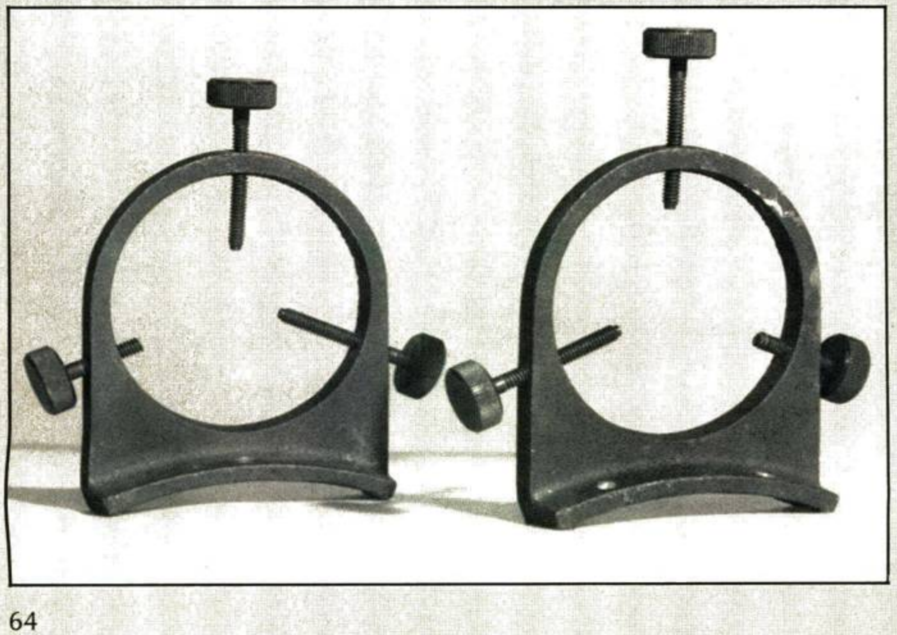
A 35mm SLR camera mounted and ready for a night of photography. This low-profile focuser is made by Kenneth Novak, Inc.











Top left: An off-axis guider fits directly behind the telescope focuser and diverts a small amount of light into an eyepiece with a prism. Photo by Art Schmidt.

Top right: Two views of a Lumicon off-axis guider show the light path and tube for a guiding eyepiece. An illuminated reticle eyepiece (second photo) contains a cross hair on which you keep a guide star centered. The cross hair is lit by a battery. Photo courtesy Lumicon.

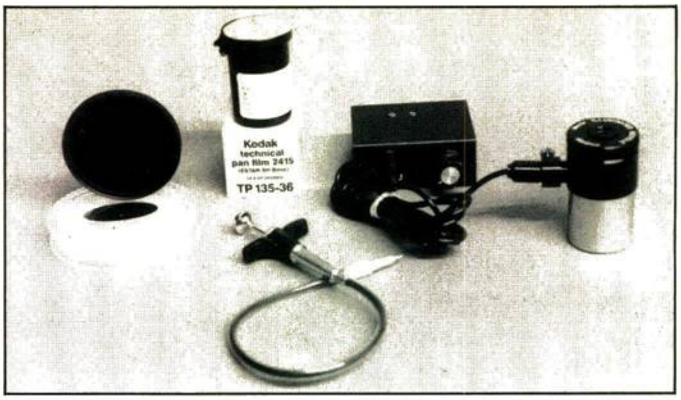
Above: A guidescope mounts on top of the main telescope tube. By moving the guidescope, you can find a suitably bright star on which to guide. Photo by Art Schmidt.

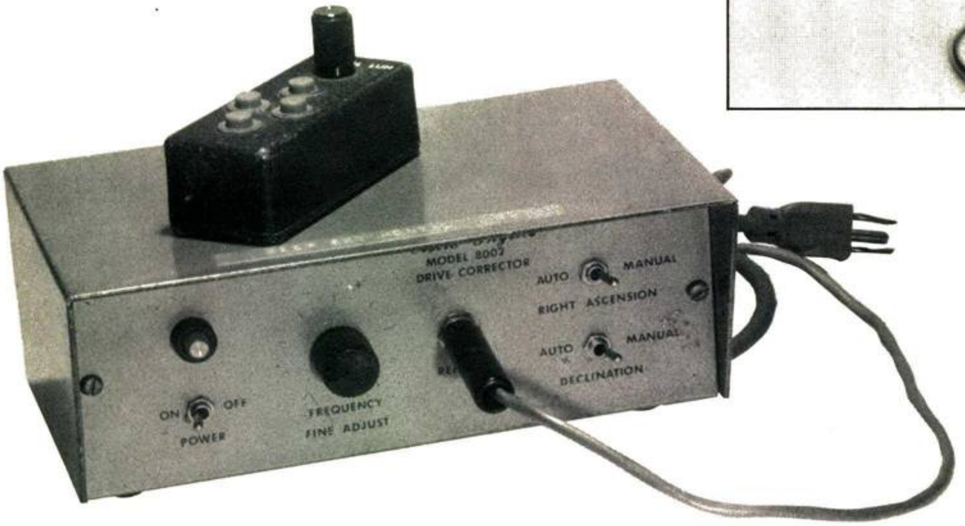
Left: Heavy-duty mounting rings lock the guidescope in place so it doesn't move during an exposure. Photo by Art Schmidt.

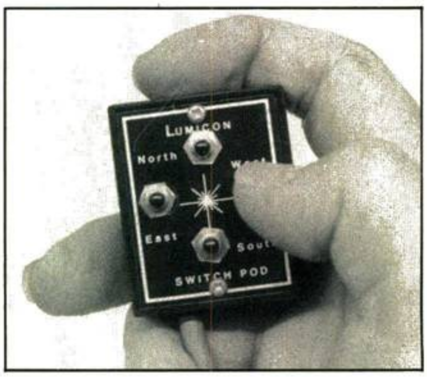
Right: Helpful accessories for the prime-focus astrophotographer: a filter, film, a cable release, and an illuminated reticle eyepiece. Photo courtesy Lumicon.

Below right: Is the guide star starting to drift to the east? A short press on the "paddle" of a typical drive corrector will recenter the star on the illuminated cross hair. Photo courtesy Lumicon.

Below: A drive corrector allows you to make small changes in the drive rate of the telescope to maintain pinpoint star images. Photo by Art Schmidt.







ward in right ascension, you can momentarily press the "west" button and cause the star to move back to its proper spot.

How will you know where the star's "proper spot" is? There are two ways of monitoring a guide star, each with its advantages and disadvantages.

The first method is to use a separate guide telescope. A guidescope mounts on top of the main telescope's tube and lets you closely watch a guide star with a high-power eyepiece. Several manufacturers offer guidescopes ranging from 60mm in aperture on up. If you're using a telescope of 8 inches or smaller, a 60mm guidescope will be adequate.

Typically guidescopes are mounted on the main telescope with a pair of large rings fitted with thumbscrews. These rings allow you to adjust the alignment of the guidescope relative to the main scope so you can find a bright guide star. One of the nicest capabilities of a guidescope is that it can be aimed up to a few degrees away from the main telescope, which ensures you'll almost always find a bright guide star. (If you move the guidescope too far from the camera field, however, you can introduce trailed stars caused by field rotation. This results from stars in the two different fields moving at slightly different rates.)

The potential disadvantage of using a separate guidescope is that the guidescope can move, or "flex," during an exposure. If flexure occurs while you're guiding, you may not have any clue that something's wrong until you see negatives with trailed stars on them. Flexure can be minimized, if not eliminated, by firmly tightening all of the bolts and thumbscrews on the guidescope before an exposure.

The second method of monitoring a guide star is with an off-axis guider. This device fits between the telescope's focuser and the camera. A small prism reflects an image of a guide star into a high-power eyepiece on the side of the tube. Because it uses light from the main telescope's optics, an off-axis guider eliminates the problem of flexure altogether. However, it also restricts your choice of guide star to the few stars that lie in the immediate area of the object you want to photograph. This isn't much of a problem if you're making an exposure of the Orion Nebula, which contains a bright cluster of stars, but if you want to photograph a dim field of galaxies in Hydra, you may have to settle for guiding on a faint star. This is certainly possible but may cause significant eyestrain after 10 or 20 minutes.

Whichever method you choose for monitoring a guide star, you'll need a special type of eyepiece to help you accurately track the star. An illuminated reticle eyepiece contains a cross hair lit by a small light-emitting diode powered by a battery pack. To use an illuminated reticle eyepiece, center the field you want to photograph in the camera, find a guide star with the guidescope or off-axis guider, center the guide star in the illuminated cross hair, and start the exposure. The trick is to use the drive corrector controls to keep the guide star perfectly centered in the cross hair. As long as the star remains centered, the stars in your photographs will be pleasingly round.

The final piece of prime-focus equipment is the camera. You'll need a 35mm single-lens reflex camera to do prime-focus astrophotography. The camera simply attaches to the telescope's focuser in place of an eyepiece. Several manufacturers offer camera adaptors for this purpose, either for 1-1/4"- or 2"-diameter focusers.

There are two criteria for choosing an astrocamera. You'll need an SLR with a mechanically operated shutter. Most "automatic" SLRs use batteries to open the shutter, which doesn't work well if you're doing long-exposure photos. The batteries may drain and close the shutter when you don't want them to. Second, the camera needs to have a clear focusing screen. Several models offer these screens, which allow you to critically focus on stars, something a ground-glass screen won't let you do. A number of models have interchangeable focusing screens so you can use a clear screen for astrophotography and a ground-glass screen for normal photography.

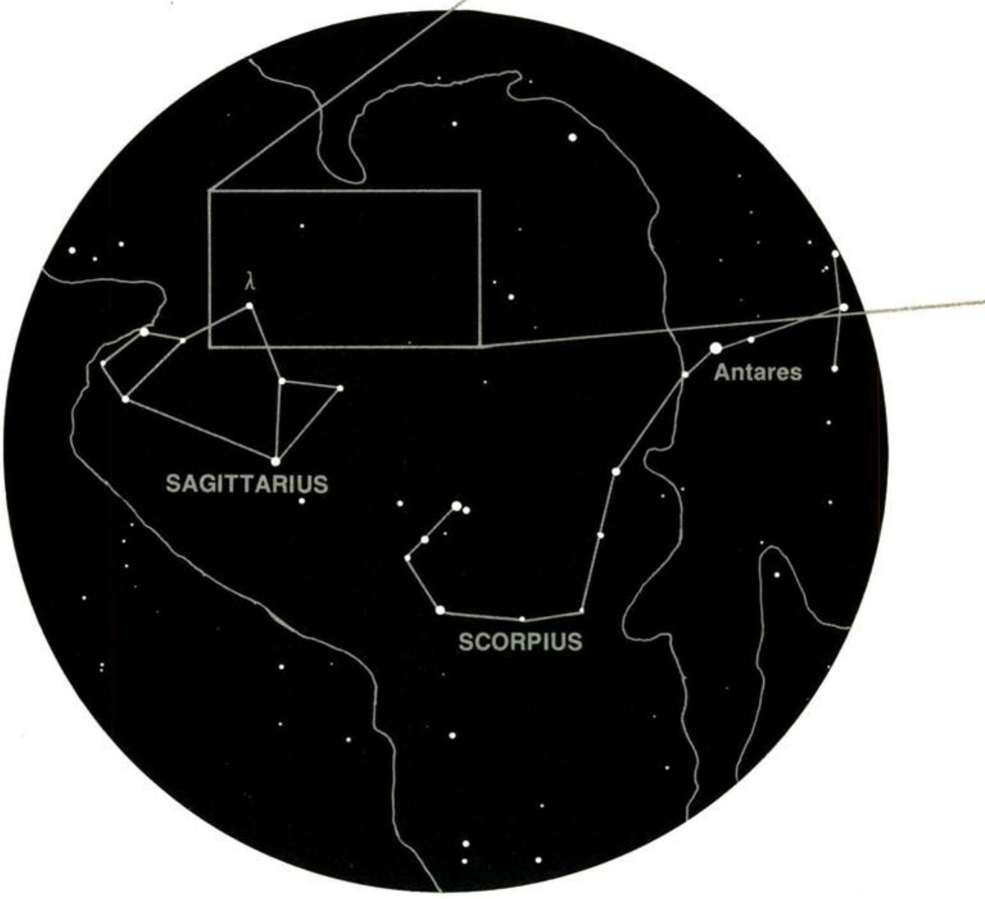
You'll also need a cable release, a long cord with a locking screw that fits onto your camera's shutter button and allows you to lock the shutter open for extended periods. If you want to make a 20-minute exposure of a galaxy, for example, set the camera shutter button on "B", press the cable release, and lock it in the closed position. When you're ready to end the exposure, unlock the cable release. Cable releases are readily available in photo supply shops.

With some fairly simple equipment and a measure of determination, you'll soon discover that prime-focus photography is a fun and rewarding way to enjoy the stars.

— David J. Eicher

Gazer's Gazette

The Saturn-Uranus Triple Conjunction



Nineteen eighty-eight is a banner year for planetary observers. In addition to the favorable apparition of Mars later this year, when the Red Planet puts on its best show in seventeen years, Saturn and Uranus pass each other three times during 1988. This rare triple conjunction is the last time the two planets will meet for forty-five years.

Saturn and Uranus lie near each other throughout the entire year and on three separate occasions Saturn passes just over 1° north of Uranus. Astronomers call such a configuration a conjunction — defined as the exact moment the right ascensions of the two objects are equal. The close proximity of the bright planet Saturn makes Uranus easier to locate this year than at any other time in the recent past. If you have never seen the elusive seventh planet before, this is your chance.

The star-rich regions of northern Sagittarius form the backdrop for the Saturn-Uranus conjunctions. The planets lie northwest of the teapot asterism in Sagittarius and some 20° to 25° east of the 1st-magnitude star Antares in Scorpius. Saturn will be obvious to the naked eye, shining about twice as bright as Antares and appearing off-white in contrast to the ruddy color of Antares.

Uranus is much fainter than Saturn, lying on the edge of naked-eye visibility. Binoculars show the planet as a blue-green point of light, and a 3-inch telescope at high magnification easily reveals the tiny disk of the planet. A pair of binoculars or a telescope with a wide-angle eyepiece will show Saturn and Uranus in the same field of view. You can then use higher magnifications to see the rings of Saturn.

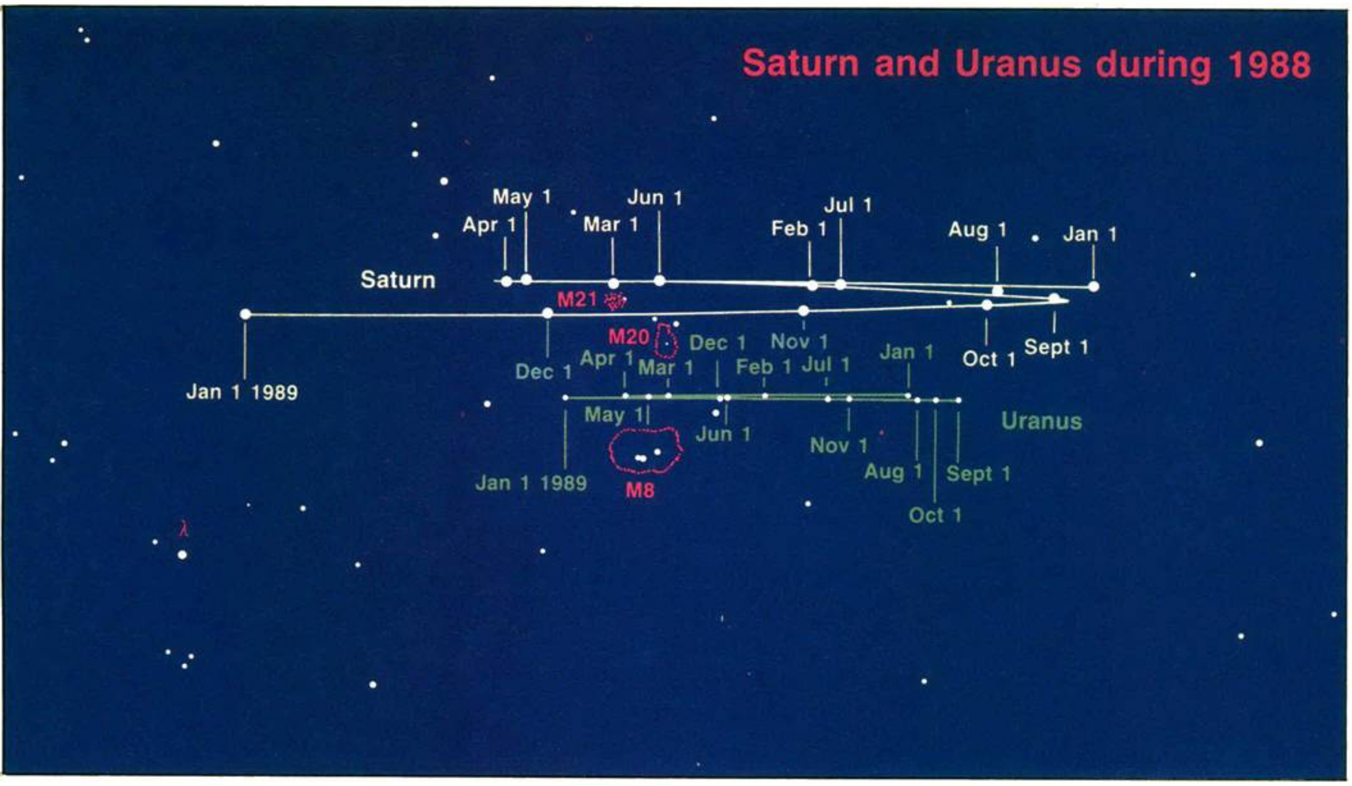
The visual appeal of the triple conjunction is further enhanced by three bright deep-sky objects that lie near the planets' paths. The Lagoon Nebula (M8) and the Trifid Nebula (M20) are glowing clouds of gas in the Milky Way that appear as indistinct patches of light; the open cluster M21 is a tightly packed collection of some seventy stars. All three objects lie within 2° of one another and all are easy to see with binoculars.

Saturn and Uranus began 1988 lost in the glare of the Sun. The two planets were very low in the southeastern sky before sunrise on February 13, the date of the first conjunction. Because the planets were so close to the Sun, this conjunction was the most difficult of the three to observe.

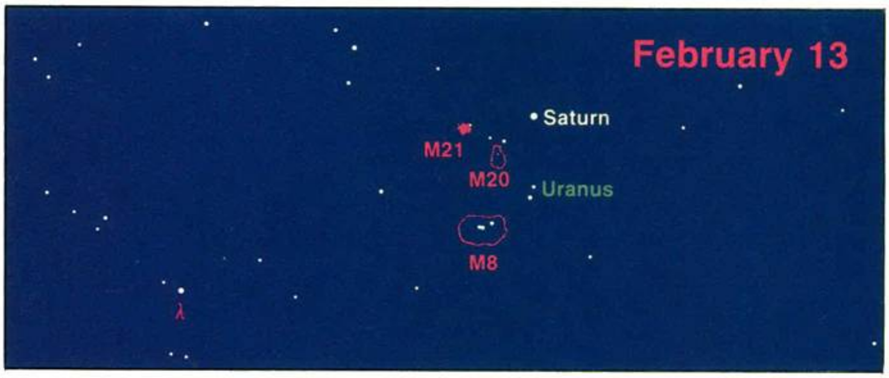
By April the two planets rise around midnight and are easy to find in the morning sky. Look to the south-southeast about one-and-a-half hours before sunrise. On April 17, the planets reach their maximum separation in right ascension between the first two conjunctions and are then 2.1° apart.

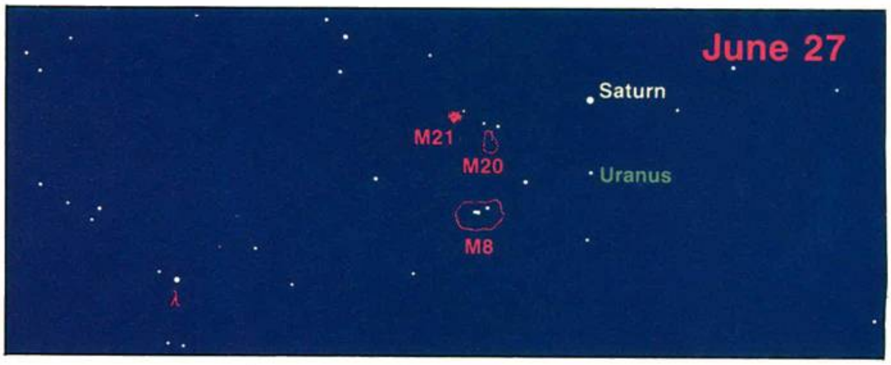
The planets continue rising higher in the sky as they approach their second conjunction on June 27 at 2h UT (10 p.m. EDT, 9 p.m. CDT, 8 p.m. MDT, and 7 p.m. PDT on June 26), when they are separated by 1.3°. Just seven days past opposition the planets are at their best visibility and above the horizon all night. They reach peak elevation about midnight and are then located directly south. At this conjunction Saturn shines at magnitude 0.0 and has a disk 18.3″ across; its rings span 41.5″. Uranus glows at magnitude 5.5 and its blue-green disk is 3.8″ across.

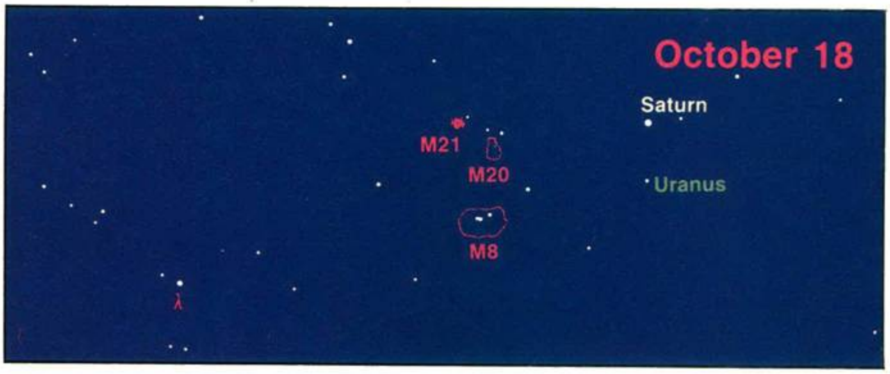
After opposition Saturn and Uranus become evening objects until they are lost in the Sun's glare in December. On August 23, they once more reach maximum separation. This time they are 1.7° apart and visible low in the south one-and-a-half hours after sunset.


Saturn and Uranus during 1988
Saturn
May 1
Apr 1
Mar 1
Jun 1
Feb 1
Jul 1
Aug 1
Jan 1
M21
M20
Dec 1
Nov 1
Oct 1
Sept 1
Jan 1 1989
Dec 1
Apr 1
Mar 1
Feb 1
Jul 1
Jan 1
May 1
Jun 1
Nov 1
Aug 1
Sept 1
Oct 1
Uranus
M8
Jan 1 1989
λ

Saturn and Uranus meet three times in 1988, and they remain close throughout the rest of the year. The two planets are located northwest of Lambda (λ) Sagittarii and some 20° to 25° east of Antares (left). A close-up view of this region (above) shows Saturn and Uranus as they travel near the Lagoon (M8) and Trifid (M20) nebulae. The positions of the planets at each conjunction are shown at right.


February 13
Saturn
M21
M20
Uranus
M8
λ


June 27
Saturn
M21
M20
Uranus
M8
λ


October 18
Saturn
M21
M20
Uranus
M8
λ

The third and final conjunction occurs low in the southwest sky at 2 UT on October 18 (10 p.m. EDT, 9 p.m. CDT, 8 p.m. MDT, and 7 p.m. PDT on October 17. This is the closest of the three conjunctions: Saturn passes just 1.1° north of Uranus. Saturn has faded to magnitude 0.5 and now appears only 15.8″ across. The rings span 35.9″. Uranus fades to magnitude 5.7 by the third conjunction and is only 3.5″ across.

The triple conjunction of Saturn and Uranus offers an excellent opportunity to observe planetary motion. Follow the planets as they move east during the first part of the year and then swing west for five months before returning to their normal eastward motion. This intricate pattern is the direct result of viewing the planets' motions around the Sun from an Earth that also revolves around the Sun.

The triple conjunction also offers a unique photographic opportunity. Not only can you capture Saturn and Uranus together, but you can also record the Lagoon and Trifid nebulae and the open cluster M21 in the same photo. A series of photographs taken throughout the year will give you a unique and beautiful record of this rare event.

— *Richard Talcott*

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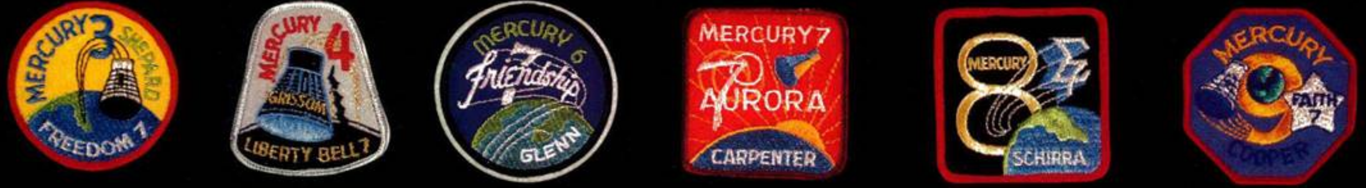
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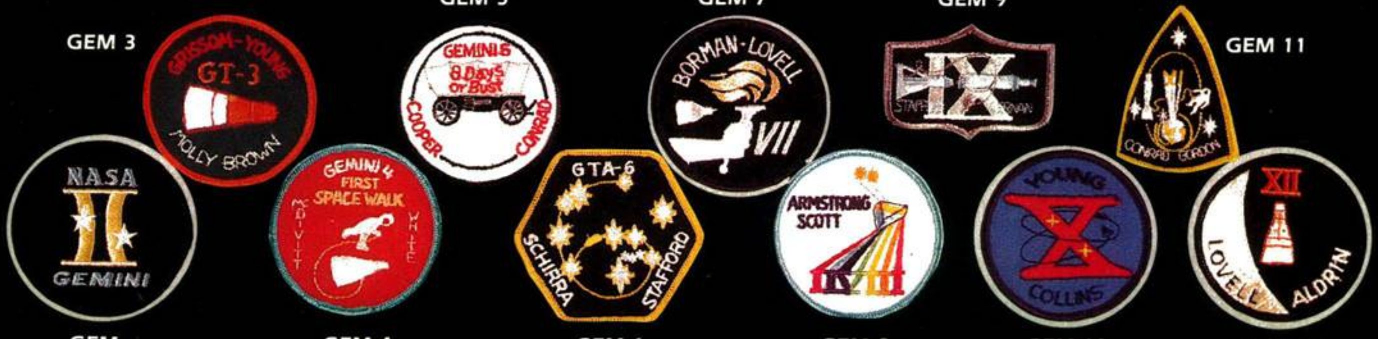
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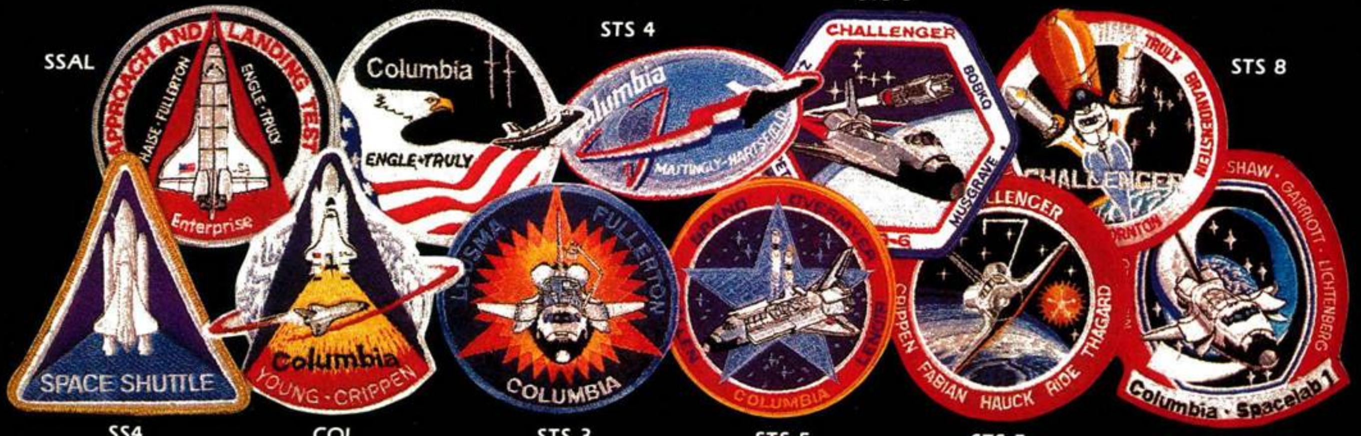
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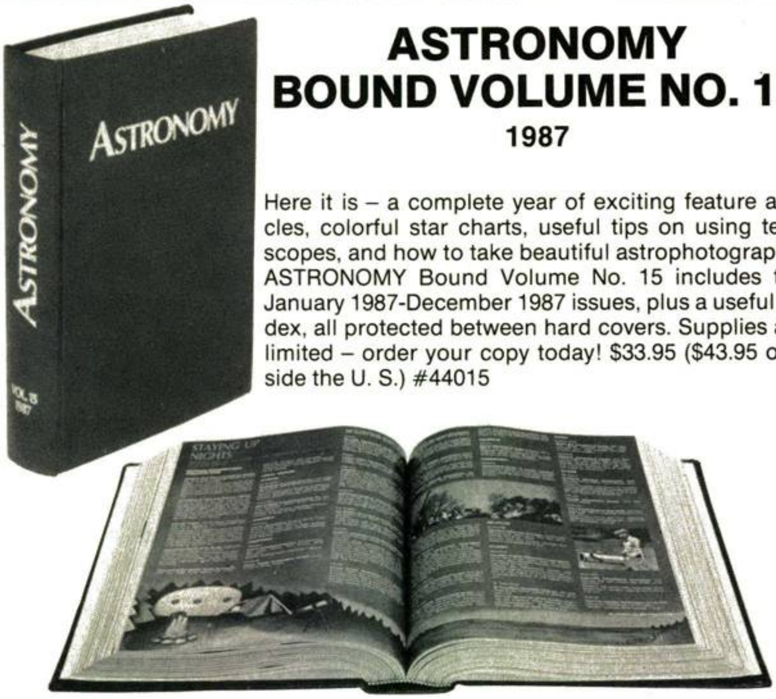

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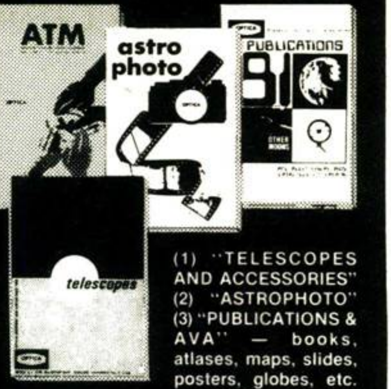

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AstroNews

SPECIAL REPORT

The 171st Meeting of the American Astronomical Society

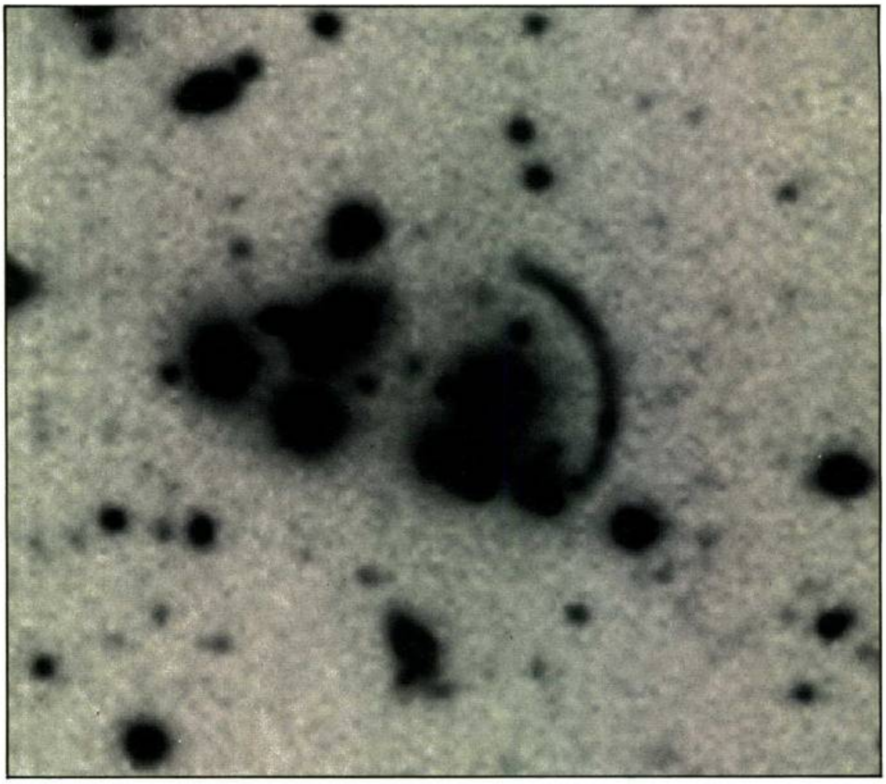
Austin, Texas — A thousand astronomers from around the world gathered here for the 171st meeting of the American Astronomical Society from January 10 to 14, 1988. The meeting was hosted by McDonald Observatory and the University of Texas at Austin.

Supernova 1987A, luminous arcs, the search for distant objects, and the large-scale structure of the universe were some of the topics presented during the four days of invited lectures, papers, and press conferences. This month's AstroNews highlights the major findings and reports from the meeting.

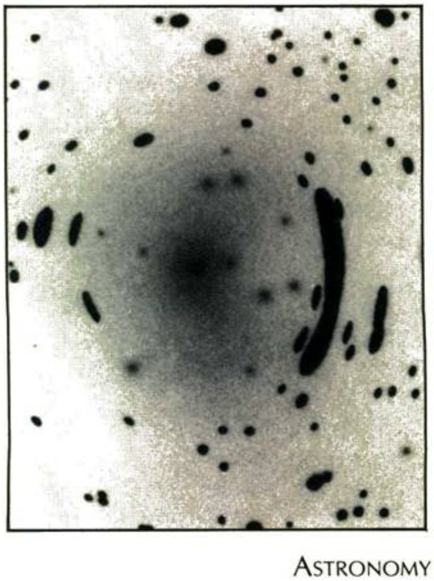
Luminous Arcs Caused by Gravitational Lensing

The discovery of giant luminous arcs in distant clusters of galaxies was one of the hottest topics at last year's AAS meeting in Pasadena, California. These symmetric arcs a few hundred kiloparsecs long — the largest optically visible structures so far seen in the universe — became the focus of several observational and theoretical studies during the past year. The results of these studies now strongly suggest that the arcs are not material objects but images of distant galaxies seen through a gravitational lens.

The idea of a gravitational lens was first proposed by Albert Einstein in 1936. His general theory of relativity explains how a massive object curves, or warps, the space around it. When light from a distant object passes through the curved space near a star or galaxy, its path is bent. If the light source is a galaxy, the object appears as a ring or as concentric arcs; if the object is a point source, the lens forms multiple images of it.



Above: Giant luminous arcs — like this one in the cluster of galaxies known as 2244-02 — are actually images of background galaxies. NOAO photo.



Right: In this computer-generated model a cluster of galaxies (the fuzzy spherical objects near the center of the image) lenses a more distant galaxy cluster. Although many arc-shaped objects appear, there is only one dominant arc. Courtesy Ramesh Narayan.

Shortly after Roger Lynds of Kitt Peak National Observatory and Vahe Petrosian of Stanford University discovered the luminous arcs, astronomers offered a number of possible explanations for the arc's nature. Among the possibilities were a light echo produced when dust in the cluster of galaxies scatters light emanating from an object at the cluster's center, stars stripped from a cluster galaxy by gravitational forces when the galaxy interacts with another cluster member or with the cluster as a whole, a region of rapid star formation induced by an expanding shock wave that originated at the center of the cluster, synchrotron radiation — radiation emitted by rapidly moving charged particles as they are accelerated by a magnetic field, and the image of a background galaxy produced by the cluster acting as a gravitational lens.

Each of these possibilities was tested observationally during the past year and many were found lacking. If the arc is a light echo, for example, the dust particles reflecting the light should also polarize the light. But observations show the amount of polarization in the arcs is very low, much lower than expected from a light echo.

The arcs might be composed of stars, either from regions of active star formation or stripped from cluster galaxies. If the stars are stripped from other cluster members, they should have spectra like the stars in the cluster; likewise, if the arcs are caused by a burst of star formation, their spectra should resemble those of the hot stars that dominate such regions.

But the spectra of the arcs appear unlike that of any normal star and thus seem to be incompatible with both hypotheses. Synchrotron radiation is an unlikely source of the arcs because all known objects that strongly emit synchrotron radiation at visible wavelengths also emit copious amounts of radio waves, and none of the arcs appears to be a strong radio source.

Lick Observatory astronomer Joseph Miller summed up the situation: "As Sherlock Holmes would say, by a process of elimination, the only explanation left, no matter how improbable, is probably the explanation — a gravitational lens."

The redshift of one of the arcs suggests that the galaxy being imaged is twice as far away as the imaging cluster. The lens thus not only distorts the distant galaxy, but it also magnifies the galaxy. Gravitational lenses may therefore offer astronomers a way to see objects that might otherwise be too faint.

But why is there only a single arc in each cluster when the simplest theory of gravitational lenses suggests there should be at least two?

Petrosian and Ramesh Narayan of the University of Arizona reported on theoretical models of the gravitational lenses. Single arcs result when the lens is not a single object. In the case of these galaxy clusters the entire distribution of matter in the cluster (a large percentage of which is concentrated in the largest few galaxies) acts as the lens. As a result the lens is "squashed" so that it is not spherically symmetric, and the lens then produces a

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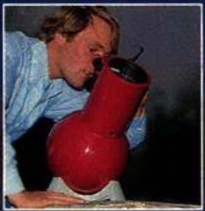

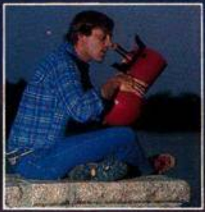

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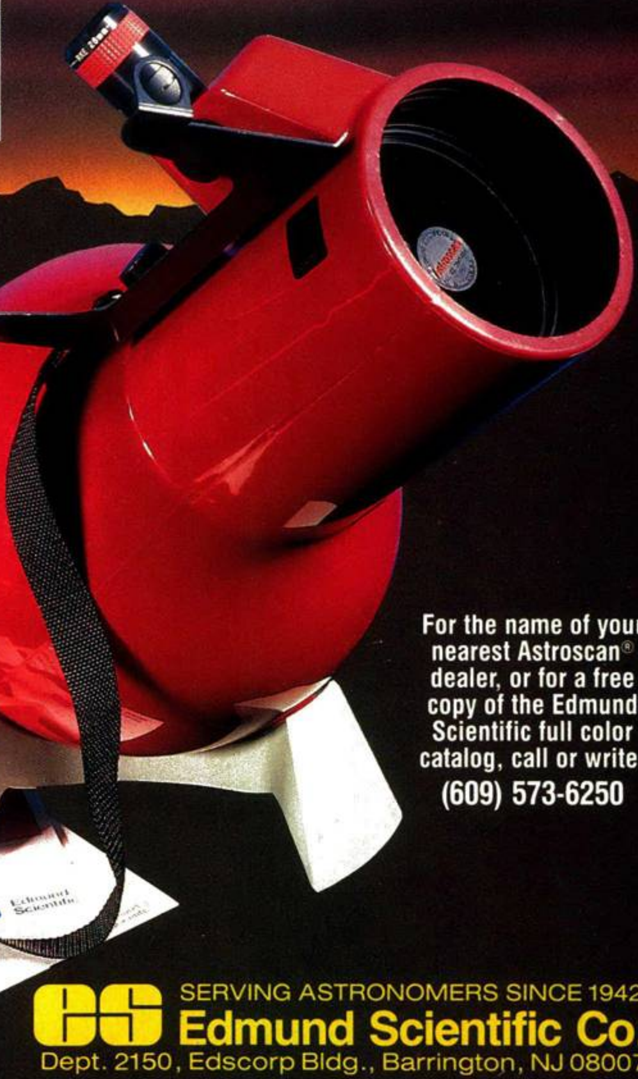

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single arc.

Petrosian, in fact, uses the arcs to probe the distribution of mass in the galaxy clusters. He has found that the mass needed to create the observed arcs is roughly 100 trillion solar masses, which is larger than the mass of the visible galaxies in the cluster, and this mass is more heavily concentrated toward the center of the cluster than the visible light is. In other words, there is a substantial amount of nonluminous matter in the galaxy clusters. Such observations may one day help us quantify the distribution of dark matter in the universe.

Gamma Rays from Supernova 1987A Emerge

Before the explosion of supernova 1987A astronomers generally accepted the idea that supernova explosions create heavy elements from lighter ones, but they had no definitive proof. At the AAS meeting three groups of astronomers provided the proof: the first detections of gamma rays from the debris of supernova 1987A.

The first experiment to detect the gamma-ray emission from supernova 1987A was the gamma-ray spectrometer aboard NASA's *Solar Maximum Mission* (*SMM*) satellite. Although the satellite was designed to look exclusively at the Sun, the supernova's gamma rays have such high energy that about one third of them still reach the spectrometer by penetrating the walls of the spacecraft.

Edward Chupp of the University of New Hampshire in Durham and Gerald Share of the Naval Research Laboratory presented the group's findings. The first gamma rays were detected in August 1987 at about the same time x-rays were discovered by instruments on the Japanese *Ginga* spacecraft and the Soviet *Mir* space station. More recent observations confirm the initial detections.

The gamma rays arise from the radioactive decay of nickel to cobalt and then of cobalt to iron. The supernova explosion produced 0.07 solar mass of radioactive nickel, which decayed rapidly into cobalt, and the cobalt in turn decayed more slowly into iron. The energy released as the cobalt decayed is in the form of gamma rays and occurs predominantly at two specific energies.

The emitted gamma rays interact with the material expelled by the explosion. Initially the debris was so thick the gamma rays could not escape. Instead, their energy heated the debris and caused it to glow in visible light. In fact, the first indirect evidence that radioactive heating was occurring in the supernova was the nearly constant decline in 1987A's optical brightness at a rate nearly identical to the declining amount of cobalt.

As the debris expanded, it became thinner, and astronomers were able to see into the inner regions of the supernova where the radioactive decay takes place. Because the visible light of the supernova is generated from the energy deposited in the envelope by gamma rays, the visible brightness of the supernova should start declining more rapidly as the gamma rays begin to escape. George Sonneborn of Computer Sciences Corporation reported at the meeting that the Fine-Error Sensor on the *International Ultraviolet Explorer* satellite — which records visible radiation — has tentatively detected a slightly accelerated dip in the supernova's brightness during recent observations.

In addition to the *SMM* results, two other groups reported detecting gamma rays from 1987A. William Sandie of the Lockheed Palo Alto Research Laboratory described observations made from a high-altitude balloon launched from Alice Springs, Australia, on October 29, 1987. The experiment detected the lower-energy gamma rays from cobalt decay but was unable to see the higher-energy gamma rays. Tom Prince of Caltech reported that his group's balloon-borne experiment, launched from Alice Springs on November 18, observed gamma rays at both energies.

The most puzzling aspect of the gamma-ray detections is how soon the gamma rays appeared. Most astronomers believed the gamma rays would remain hidden in the expanding shell of material until late in 1987. The early observations imply that 1 or 2 percent of the cobalt has managed to penetrate the envelope, either as blobs expelled during the supernova explosion or by mixing with material in the envelope.

Now that gamma rays have directly confirmed theoretical predictions about the synthesis of elements in supernovae, experimenters are eager to see how the gamma-ray intensity varies with time. The *SMM* will continue monitoring supernova 1987A and more balloon flights are scheduled for March. These measurements will add a great deal to what we already know about the nature of the explosion.

Mysterious Objects May Be Youngest Galaxies

A group of astronomers from the University of Arizona believes it has observed galaxies forming at the edge of the universe. If this interpretation is true, the "primeval galaxies" are more distant than the most distant quasars.

Since the mid-1960s astronomers have argued that young galaxies should be common in the far reaches of space. Blazing from the light created during a rapid burst of star formation, primeval galaxies are nevertheless so far away they appear faint, and the effort to find them strains the limits of modern observational astronomy. Yet the potential reward for their discovery is great: primeval galaxies promise to yield important clues about the formation of galaxies and the large-scale structure of the universe.

Coworkers Richard Elston, George Rieke, and Marcia Rieke found the new class of objects while searching for primeval galaxies at infrared wavelengths. With a powerful new infrared camera attached to the 61-inch telescope at Steward Observatory in Arizona, the observers imaged 8 square arcminutes of sky at a wavelength of 2 microns.

The researchers compared the infrared images with optical observations they made with Steward Observatory's 90-inch telescope on Kitt Peak. These observations, made in the red region of the visible spectrum, helped establish the colors of the objects. The astronomers then used the colors to deduce more about the objects' nature.

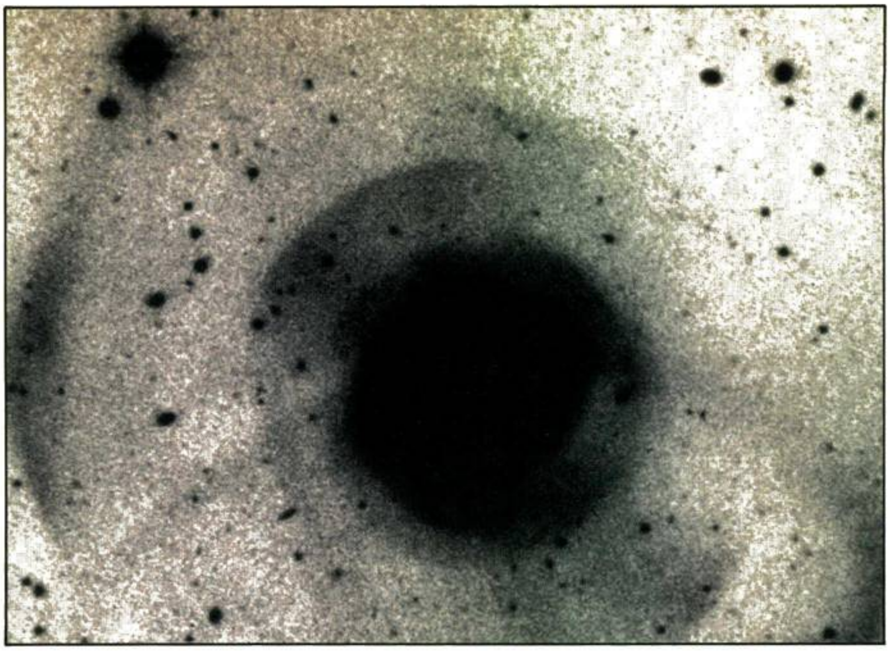
Two objects in particular stood out from the rest. Both had angular diameters of 5 arcseconds, were very bright in the infrared (17th magnitude), and about twenty times brighter in the infrared than in the red part of the spectrum. The last two observed characteristics are not displayed by any normal galaxy and should not be seen in any normal galaxy at any distance from Earth. And because quasars appear as points of light in the sky, the 5-arcsecond angular diameters of the objects eliminate quasars as a possible explanation.

A primeval galaxy, however, should display such characteristics. Young galaxies would experience a rapid burst of star formation that would cause the galaxy to be highly luminous. And the galaxies would form early in the history of the universe, which means they would have to be very far away and thus display a huge redshift.

In fact, the redshift of these objects can be estimated from the observed brightnesses at the two wavelengths. Astronomers believe neutral hydrogen gas in a primeval galaxy should absorb most radiation with a wavelength shorter than 912 angstroms. Thus, a primeval galaxy will be very dim at shorter wavelengths and brighter at longer wavelengths.

The sharp rise in brightness from red to infrared wavelengths in the newly discovered objects may record the break expected at 912 angstroms shifted to a wavelength between the two measured bands. If true, the objects' redshifts must be between 6 and 25. (The precise redshifts cannot be determined from the observations.) The most distant quasar yet discovered has a redshift of 4.5, so if this interpretation is correct, the primeval galaxies are not only the most distant galaxies but also by far the most distant objects in the universe.

Elston emphasizes that this preliminary work needs to be confirmed, and the Arizona astronomers plan to make additional observations of these objects with the Multiple Mirror Telescope on Mount Hopkins. By observing at several wavelengths between the two they have used so far, the astronomers hope to pin down the nature of these objects better. Until new observations clarify the situation, Elston believes the fascinating objects are "excellent candidates for primeval galaxies."



The disk galaxy NGC 474 shows several ripples, presumably material accreted from the outer disk of the nearby spiral galaxy NGC 470 (outside the field of this image) during a recent close encounter. Such ripples may support the theory that the central bulges in disk galaxies form after the disks. Photo courtesy Francois Schweizer and Patrick Seitzer.

Faint Ripples Shed Light on Galaxy Evolution

Faint ripples of luminous matter may be telling astronomers that previous theories of galaxy formation are wrong. These ripples suggest that the disks of spiral galaxies form before rather than after the central core does.

Ripples have been found in nine relatively nearby disk galaxies. These ripples, or shells, are faint, arc-shaped enhancements that glow with only a few percent of the surface brightness of the galaxies. They appear to be luminous matter falling into the galaxy from a companion galaxy and may provide important clues to the evolution and formation of disk galaxies.

Astronomers Francois Schweizer of the Carnegie Institution of Washington and Patrick Seitzer of the National Optical Astronomy Observatories announced their discovery at the January meeting of the AAS. The astronomers imaged seventy-two disk galaxies of Hubble classification types S0, S0/Sa, and Sa with a 36-inch telescope on Kitt Peak in Arizona. The CCD images were computer processed to bring out the ripples.

Similar ripples had previously been found in elliptical galaxies. Computer simulations of interacting galaxies show that ripples form when luminous matter from a nearby galaxy is drawn toward the elliptical and when two galaxies collide and merge. The new observations imply that a similar process is taking place in the observed disk galaxies.

Disk galaxies have two distinct components: a central bulge of stars that resembles an elliptical galaxy and a flat disk composed of stars, gas, and dust. Most astronomers believe the bulge and its stars form rapidly during the collapse of a protogalactic cloud of gas, and the disk stars form later after the gas and dust settle into a disk.

The discovery of ripples could change this view. Ripples are relatively short-lived events — with lifetimes of only 1 billion or 2 billion years — and yet observations indicate that the matter in the ripples accretes to the bulge of the galaxy. The recent accretion of bulge material implies the bulge may be younger than previously thought.

"Taken by themselves," said Schweizer, "our observations hardly constitute incontrovertible *proof* that bulges formed after the disks through accretion and mergers of smaller galaxies." But he added that there is growing evidence that young stars exist in some central bulges and that bursts of star formation take place in the bulges of colliding galaxies. This evidence suggests the bulges in disk galaxies may form after the disks. In this scenario the collapse of a protogalactic gas cloud can only form a disk, and it is the subsequent collision of such disks that leads to the formation of the central bulges in disk and elliptical galaxies.

ASTRONOMY
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Astronomy Weekend, Davis, West Virginia. Contact: Pat Northeimer, Blackwater Falls State Park, P.O. Box 490, Davis, WV 26260. Phone: 1-800-CALL WVA.

April 23
Astronomy Day Celebration (exhibits, talks, shows, demonstrations, and a star party sponsored by the Northwest Suburban Astronomers), Hoffman Estates, Illinois. Contact: Bob Long, 4960 Chambers Drive, Barrington, Illinois 60010. Phone: (312) 991-7432.

April 23
15th Annual Astronomy Day. Contact: Gary E. Tomlinson, Chaffee Planetarium, 54 Jefferson Avenue SE, Grand Rapids, MI 49503. Phone: (616) 456-3985.

May 7
Astronomy Day (displays, video and planetarium programs, a telescope-making workshop, and a starwatch sponsored by the Wilderness Center Astronomy Club), Wilmot, Ohio. Contact: Robin Bill, 558 Canford Avenue NW, Massillon, OH 44646. Phone: (216) 833-9399 (evenings).

May 9-15
Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: TSP Registrar, 6433 Cedar Hollow, Dallas, TX 75248.

May 14
14th Annual Virginia Association of Astronomical Societies Convention (sponsored by the Back Bay Amateur Astronomers), South Hampton Roads, Virginia. Contact: Glen Howell, 2808 Flag Road, Chesapeake, VA 23323.

May 14
North Central Region of the Astronomical League Annual Convention (hosted by the Marquette Astronomical Society), Northern Michigan University, Marquette, Michigan. Contact: Jeanne Shibley, Registrar, 412 High Street #1, Marquette, MI. Phone: (906) 225-1066.

May 27-30
Riverside Telescope Makers Conference, Camp Oakes, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Avenue, Riverside, CA 92503. Phone: (714) 689-6893.

June 5-9
172nd Meeting of the American Astronomical Society (professional meeting), University of Kansas, Kansas City, Missouri. Contact: American Astronomical Society, 2000 Florida Avenue, NW, Suite 300, Washington, DC 20009.

June 17-19
13th Annual Association des Groupes d'Astronomes Amateurs Congress (sponsored by the Royal Astronomical Society of Canada, Quebec Center), Sainte-Foy, Quebec, Canada. Contact: R.A.S.C., Quebec Center, P.O. Box 9396, Sainte-Foy, Quebec, Canada G1V 4B5. Phone: (418) 626-9592.

June 25-26
The Universe in the Classroom (weekend credit workshop on teaching astronomy in grades 3-12 for U.S. and Canadian teachers, sponsored by the Astronomical Society of the Pacific and the Royal Astronomical Society of Canada), University of Victoria, Victoria, British Columbia, Canada. Contact: Teachers Workshop, A.S.P., 1290 24th Avenue, San Francisco, CA 94122.

June 25-July 2
100th Annual Meeting of the Astronomical Society of the Pacific, jointly sponsored by the Royal Astronomical Society of Canada and the Western Amateur Astronomers, University of Victoria, Victoria, British Columbia, Canada. Contact: A.S.P., Summer Meeting Department, 1290 24th Avenue, San Francisco, CA 94122.

June 29-July 4
International Planetarium Society Convention, Richmond, Virginia. Contact: Ken Wilson or Eric Melenbrink, Universe Planetarium, 2500 West Broad Street, Richmond, VA 23220. Phone: (804) 257-0211.

July 27-30
ALCON, the 1988 Astronomical League Convention jointly sponsored by the Association of Lunar and Planetary Observers, Iowa Western Community College, near Omaha/Council Bluffs, Nebraska. Contact: George E. Allen, 3390 South 130th Street, Omaha, NE 68144. Phone: (402) 333-1097.

July 27-30
The Teaching of Astronomy (colloquium sponsored by the International Astronomical Union), Williams College, Williamstown, Massachusetts. Contact: Jay M. Pasachoff, Department of Astronomy, Williams College, Williamstown, MA 01267.

August 10-14
5th Annual Mount Kobau Star Party (observing, telescope-making and astrophotography contests, speakers), Okanagan Valley, British Columbia, Canada. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, British Columbia, Canada V1T 1P4. Phone: (604) 545-1226.

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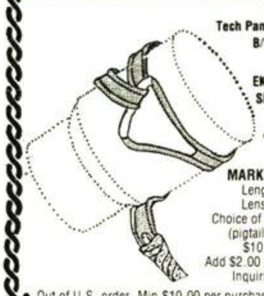

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Gazer's Gazette

Warning: Globular Clusters Can Change Your Life

It might happen to you too. My fascination with globular star clusters began one night when on a whim I decided to tag along to a star party held by the local astronomy club in Oxford, Ohio. A group of would-be stargazers went to the club president's house where a little 4-inch reflecting telescope had been set up. The house was located in a subdivision only a couple of miles outside of town, so the sky was only somewhat dark. The club president told me to peer into the telescope's eyepiece. I did, and there it was. A fuzzy ball of light speckled with glowing dots of light. It looked like an illusion, something too eerie and magical to have been produced by nature. The club president told me to peer into the telescope's eyepiece. "That's M13 in Hercules," he said. "What's M13?" I asked. He told me M13 was the best globular star cluster in the northern sky. "What's a globular cluster?" He responded somewhat mysteriously, "Oh, you'll find out. There might even be a globular cluster in your future!"

I came away from that night reeling with excitement, as if I'd suddenly been let in on a closely guarded secret. I hadn't changed. The world around me hadn't changed. But I felt profoundly different about walking down the street or tying my shoes or buying a soda at the supermarket. I was keenly aware as never before that out beyond the blue sky lay vast numbers of stars and countless worlds unseen. I couldn't help feeling differently. I had the whole universe on my mind.

More than anything else I remembered that glimpse of M13. That was the cause of it, the globular cluster. Day passed into night and it was dark again, but the sky was cloudy. Because I couldn't call the club president and persuade him to go out observing again, I decided to try to learn something about globular clusters. What are these things anyway?

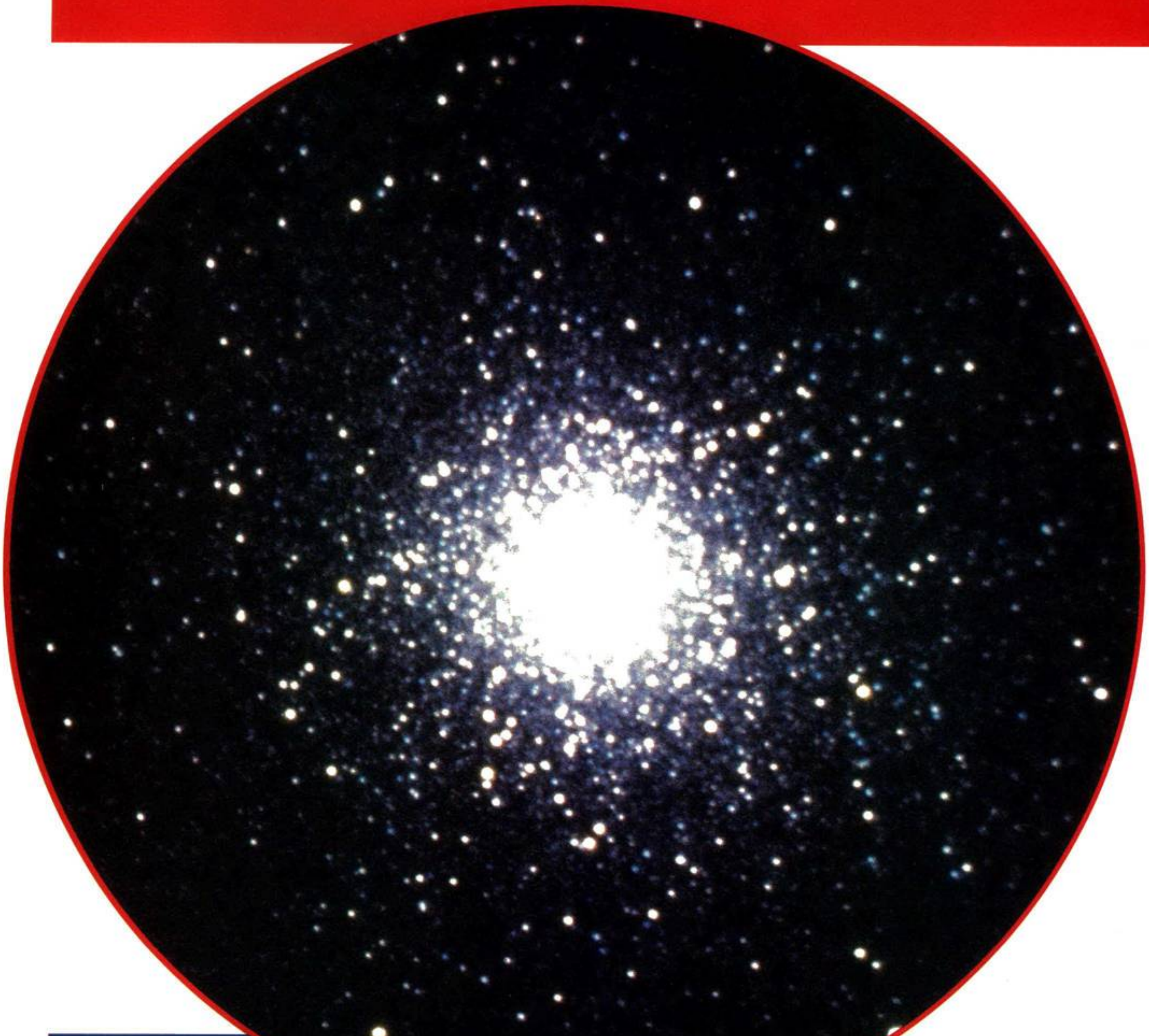
In the *Encyclopedia Americana* I read that globular clusters are big balls of stars. (I knew as much by just looking at M13.) But why do these balls of stars form the way they do? Where do they fit into the scheme of things? How big are globular clusters? As I fell asleep that night, thoroughly discouraged by the cloudy sky, a thousand puzzles raced through my mind, puzzles of stars, globular clusters, galaxies, and life on other worlds.

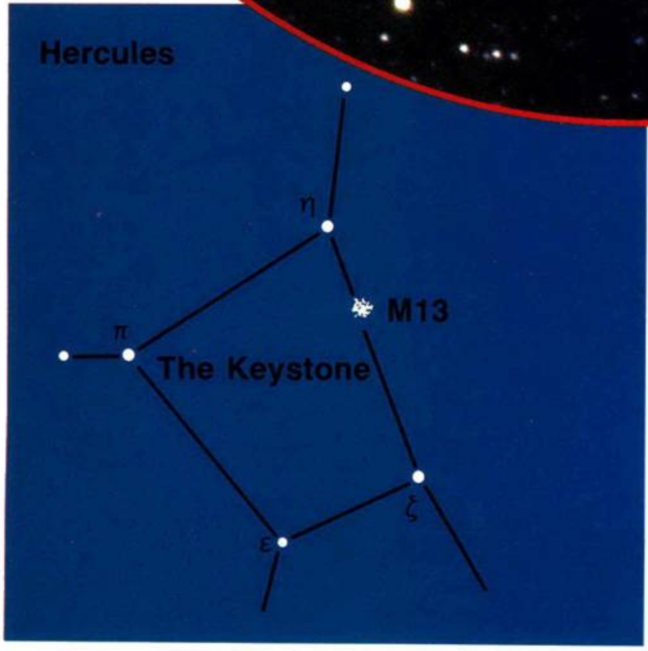
I ultimately did find out about globular clusters. Through many nights of observing in my backyard and many days of reading books and magazines, I searched for information on globular clusters wherever I could find it. I soon found that these vast balls of stars are relics of the ancient past that formed billions of years ago when our Milky Way Galaxy formed. Because they are so old, globular clusters hold clues to the infancy of the Galaxy. The Milky Way is basically a flattened disk of stars, gas, and dust. Almost all of the stars, gas clouds, planets, and whatever else the Galaxy contains lie within this flattened disk of material. The disk is surrounded by a tenuous halo of dust. Globular clusters orbit about the center of the Galaxy in this outer halo, isolated from the more crowded, active life in the Galaxy's disk.

This was fine and good, and I could accept it as sensible and not too far-fetched, but that still didn't explain how globular clusters came to be in the outer reaches of our Galaxy. From checking *The Cambridge Encyclopaedia of Astronomy*, I found that most cosmologists, astronomers who study the origin of the universe, believe the Milky Way formed from a great spherical cloud of matter accumulated by the force of gravity. As this cloud collapsed, most of the material concentrated around a great central nucleus and eventually flattened into a rotating disk. The small clumps of matter that didn't make it close to the Galaxy's center, however, coalesced into globular clusters.

A few weeks after first seeing M13 I had the chance to chat with a physics professor. Naturally I was dying to learn the real poop on these star groups. "What are globular clusters really like?" I asked. He suggested that I think of globular clusters as mini-galaxies. "But globular clusters are small compared to spiral galaxies like the Milky Way," he said. "They measure only about one four hundredth the length of a galaxy like ours. They are little isolated communities of stars bound together by gravity, stars traveling together through space."

That was all I could take. Little isolated





Above: The great globular cluster M13 in Hercules is a big ball of stars easily visible in backyard telescopes. Together the stars' light is sufficient to make M13 faintly visible to the naked eye; this photograph approximates the view through a telescope 16 inches in aperture. Photo by Bill Iburg.

Left: M13 is easy to locate. Although its host constellation, Hercules, isn't the brightest in the sky, M13 can be found between the brighter star groups Lyra and Bootes. Once you've found Hercules, locate the "keystone," the central, brightest part of the constellation. M13 lies on the western side of the keystone between the stars Eta (η) and Zeta (ζ) and just a hair closer to Eta.

groups of stars traveling together around the Milky Way — these globular clusters have some nerve! I had seen M13 several times since that first experience, but the professor told me many globular clusters were visible in small telescopes. I went out under the stars to see what the others looked like. I chose the next reasonably clear night as the time and the bright globular cluster M3 in Canes Venatici as the target. You too can spot this globular cluster with a small telescope, and it is well placed for observing on any spring evening.

Finding M3 proved to be slightly more challenging than finding M13 had been. M13 lies on the western side of the "keystone" figure in the center of Hercules, a faint, sprawling group of stars between the brighter constellations Lyra and Bootes. M13 is easy to locate because it lies near bright, easily recognizable stars. But M3 offers the challenge of spotting a globular cluster without bright, easily recognizable stars in the immediate vicinity.

To find M3, you start by aiming your telescope at Arcturus, the brilliant yellowish star in Bootes, a kite-shaped constellation. Move the telescope toward the west to a pair of bright stars designated Eta and Tau Bootis. Next move the telescope due north, watching in the low-power eyepiece as you go. After a minute or so of careful sweeping, you should see a faint star creep into the field of view and along with it the fuzzy disk of globular cluster M3.

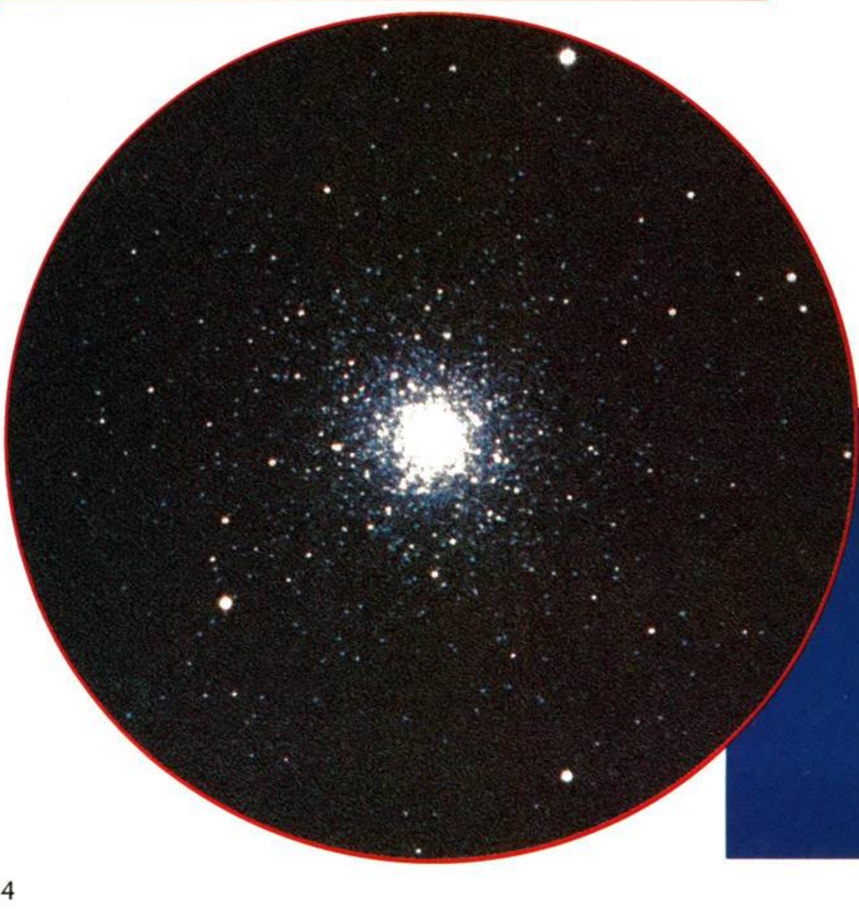
Although M3 is slightly smaller and fuzzier than M13, M3 is a very attractive globular cluster. It consists of a greenish gray disk of light with a sprinkling of individually resolved stars, especially around the disk's edges. When I first saw M3, I stared in amazement. A little chunk of matter circling the Milky Way in a lazy orbit? A great globe of stars as old as the Galaxy itself? M3 was a marvelous sight, and as I looked I began to notice for the first time that a few of the stars seemed to show slightly different colors.

Of the cluster's approximately half million stars, I was able to see only the brightest few dozen. Most of these appeared distinctly yellowish, but a few of the bright points of light had a burnt-orange color. I later checked in ASTRONOMY and found that these stars are red giants, huge, relatively cool stars compared with the hot blue stars back in the Galaxy's disk. The stars in globular clusters are extremely old, and they last so long only because, unlike the hot blue stars, they burn nuclear fuel at a slow, conservative rate. In every book I checked the same descriptions of globular cluster stars kept cropping up: they're ancient relics of the past. Why are there no young stars in globular clusters?

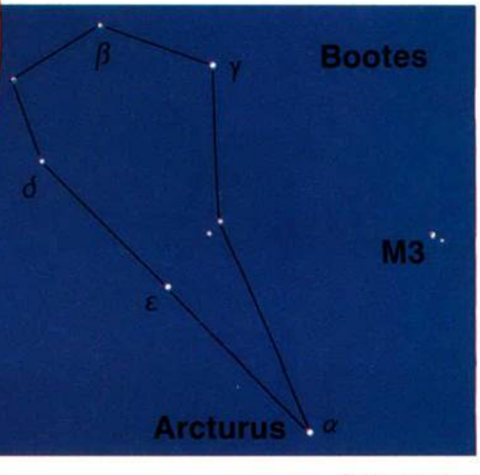
Young stars form from condensing gas clouds as the Milky Way Galaxy did, only in a much smaller area. A cloud of dust and gas contracts from gravity and at some critical point gathers enough material to "turn on" and begin shining and giving off heat and other forms of energy. Globular clusters contain lots of old, slowly burning stars, yet when it comes to producing new stars, they are doomed to sterility. Because the orbits of globular clusters periodically carry the clusters through the disk of the Galaxy, the gas and dust in the cluster gets swept out of the cluster. So globular clusters will, given enough time, slowly burn out like cooling embers.

Several days after I saw M3, I was ready to seek out my third globular cluster. M5 in Serpens Caput would be relatively easy to find and about as bright as M3. With M5, however, I began to learn the basic techniques of observing. M5 is a good object to practice finding and learning observing techniques for you too.

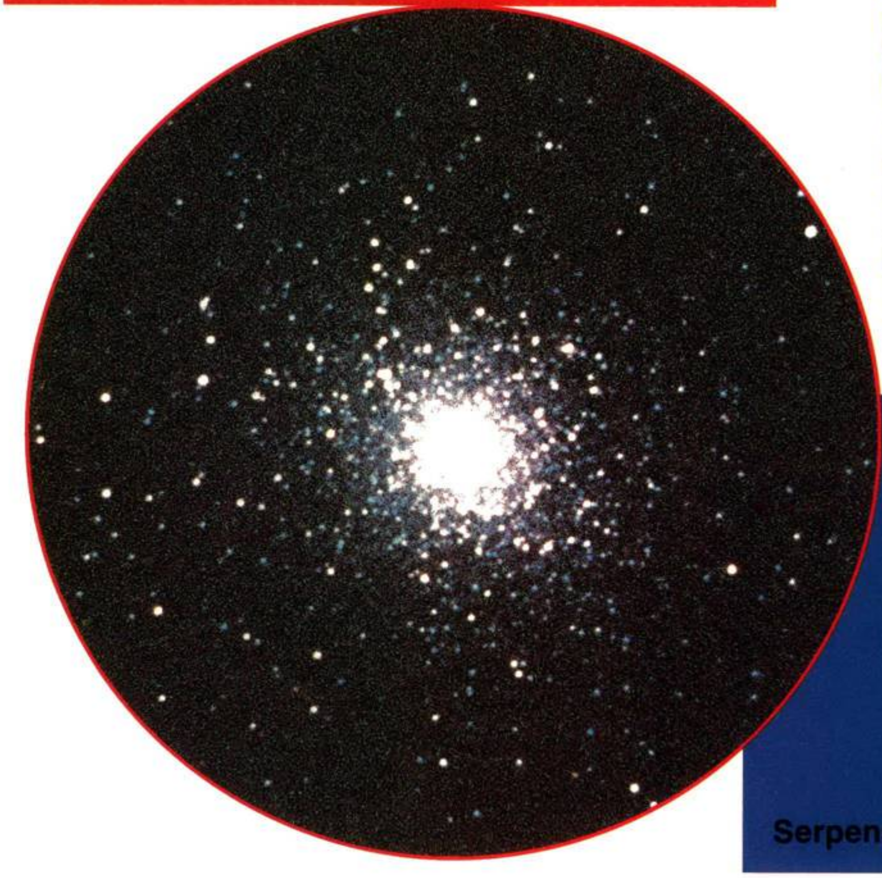
It's best to use the lowest power eyepiece you have when initially searching for an object. This provides the biggest possible area of sky in the eyepiece so you can sweep around in the vicinity of an object and have the greatest chance of running across it. Serpens Caput is not an obvious star group, but you'll be able to see it below Hercules by using the center spread star map in this issue. Point the telescope at the brightest star in the area, Alpha Serpentis, and check a star atlas for M5's position. After spending a few min-



Left: The Reverend T. W. Webb, a famous nineteenth-century watcher of the skies, described the globular cluster M3 as a "beautiful globular congregation of not less than 1,000 small stars, *blazing* splendidly, that is, running up into a confused brilliancy towards the center." Photo by Roger Sliva.

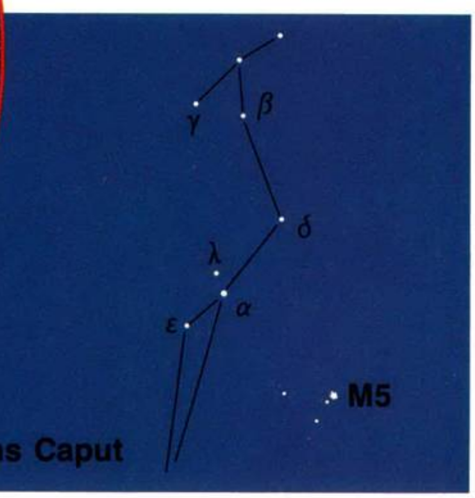


Below: Although M3 lies in the faint constellation Canes Venatici, the bright group of stars that includes Bootes and its shining beacon Arcturus provides a better starting point for finding the cluster. M3 forms a near-right triangle with Arcturus and the star Epsilon Bootis and lies next to a faint star.



Left: Globular clusters like M5 in Serpens Caput may stretch 100 light-years across — over sixty times the diameter of the solar system — and contain half a million stars. The night sky viewed from a planet inside such a cluster would sparkle with hundreds of stars, each as bright as Venus is in our sky. Photo by Roger Sliva.

Below: M5 is not difficult to find once you familiarize yourself with Serpens Caput, a winding constellation of bright stars running north-south. M5 lies just above a bright triangle of stars southwest of the central part of Serpens Caput.



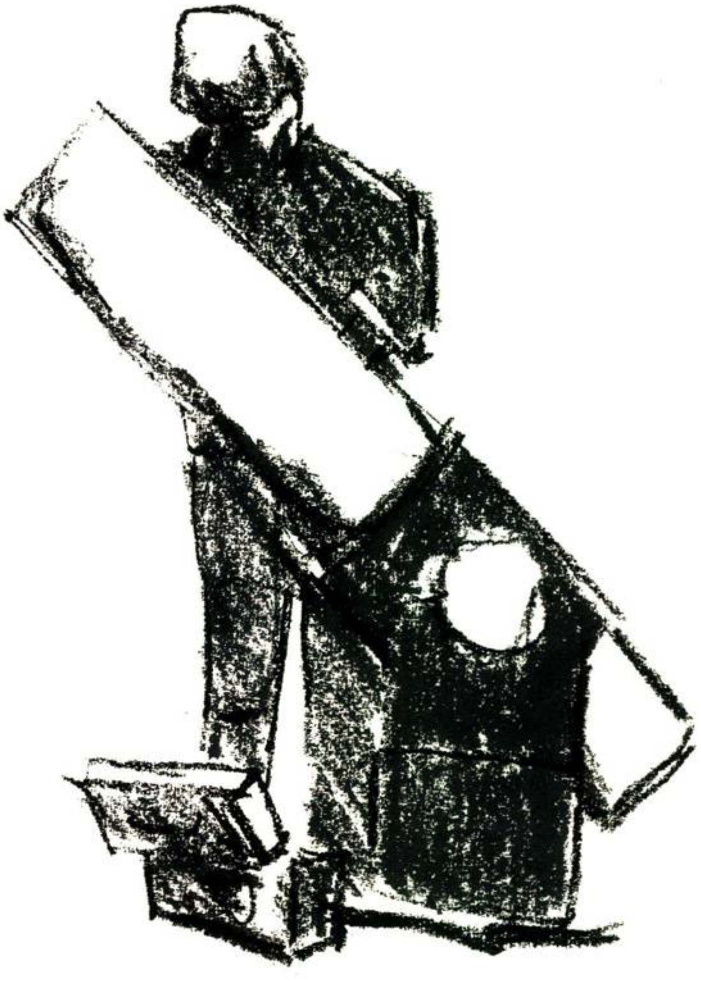
utes learning the patterns of stars between Alpha and M5, you shouldn't have much trouble finding the cluster. Look through your finder scope and move the telescope down to a triangle of bright stars. Now look carefully in your finder scope and you should see M5 as a fuzzy "star" just above this triangle.

Once you've found M5, insert a higher power eyepiece to look more closely at the cluster. When I first gazed at M5, the atmosphere was steady and the brightest stars in the cluster stood out clearly. I found that when I glanced toward the edge of the field of view, the detail visible in the cluster improved. "Averted vision" utilizes the acute sensitivity of peripheral vision. The image falls on the eye's rod receptors, which are especially good at detecting faint light.

I also noticed that moving the telescope around very slightly, which caused the image of the globular cluster to move to different parts of the field, made it easier to see faint details in various parts of the cluster. The human eye is acutely sensitive to motion.

There are about 125 globular clusters visible in backyard telescopes, and these clusters span a wide range of brightnesses and sizes. Some of them are easy to find, some are not. But all are relics of the past, nearly unchanged reminders of a time long ago when the Galaxy was young.

— *David J. Eicher*



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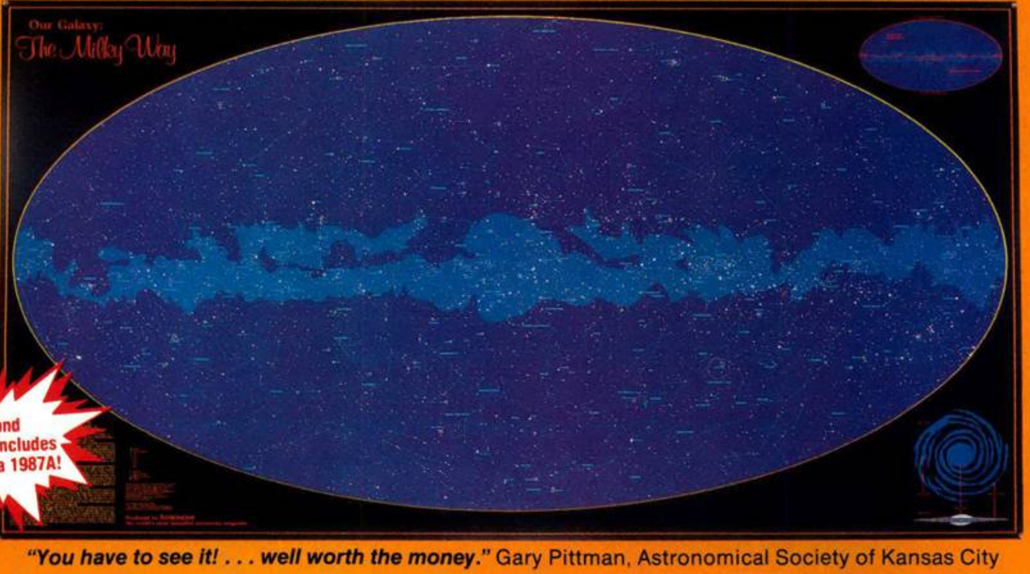
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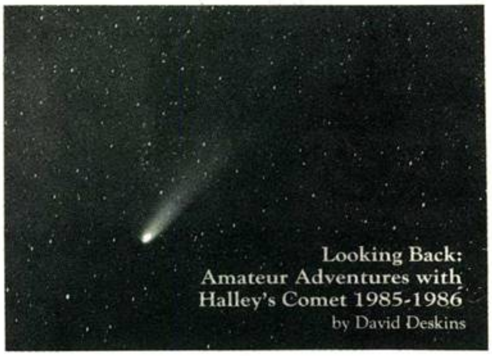
Looking Back: Amateur Adventures with Halley's Comet 1985-1986



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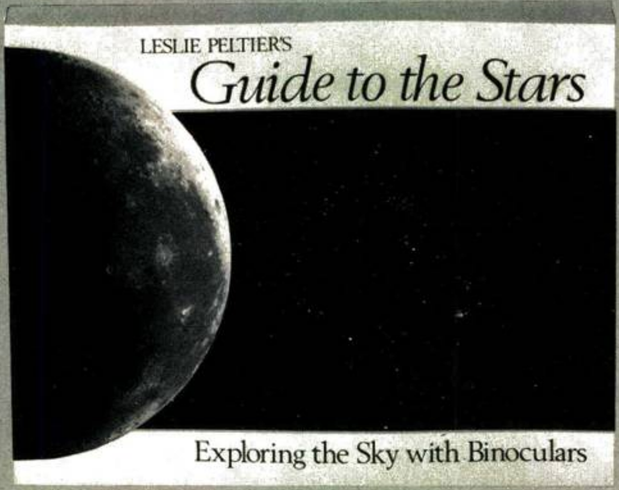

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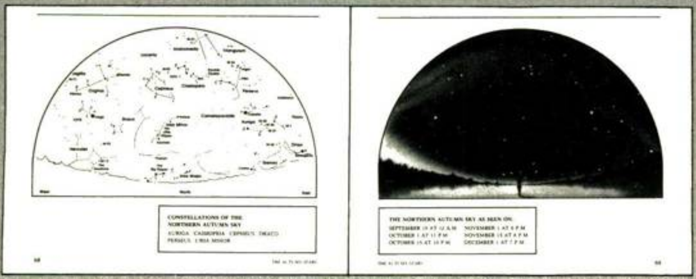

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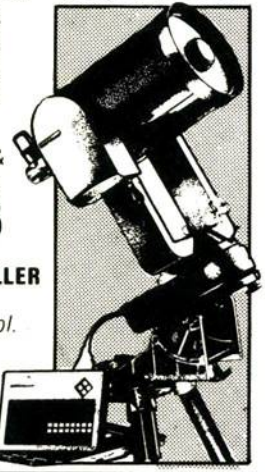

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Reader Reports

Comet Bradfield Grows an Antitail

Backyard observers love a good comet. And during the last two months of 1987 5th-magnitude Comet Bradfield qualified as a good comet, sprouting a 2° tail and a short antitail as it arced its way across Ophiuchus, Aquila, and Pegasus. In fact, many observers enjoyed viewing Bradfield's comet more than Comet Halley in 1986. Besides observing Comet Bradfield, readers have been busy taking pictures of a distant supernova and finding new ways of recording rich star colors on film.

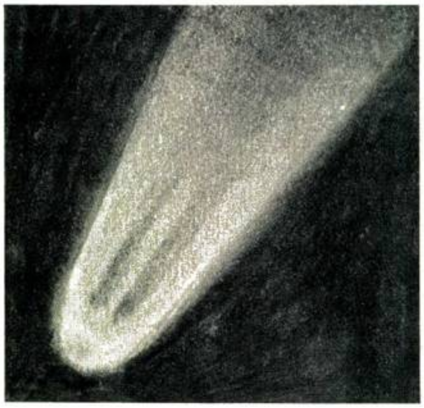
Comet Bradfield 1987s

Gradually brightening throughout October, Comet Bradfield reached perihelion on November 7, and became the year's brightest comet. By early December Bradfield shone at a peak magnitude of 5.3, and observers could see the comet's tail extending across 2° of sky — some four Moon-diameters. By the last week of December the comet had faded to 6th magnitude. But, as if to compensate, the comet developed an antitail, a stream of matter appearing to flow toward the Sun and stretching over 1° of sky. Actually this antitail is caused by a perspective effect, from sunlight striking dust left in the wake of the comet.

Although Comet Bradfield wasn't as bright as Comet Halley, many observers drew comparisons with the much-maligned Halley and seemed to enjoy viewing Bradfield more than its better-known cousin. "Of the comets I've seen in the past fifteen years — over fifty in all — this one is a real gem," wrote Chris Schur of Black Canyon City, Arizona. "On the evening of December 20, Pierre Schwaar and I photographed Comet Bradfield. To my surprise the comet revealed a new feature not seen on the previous nights, an easy-to-see antitail, which I traced out to 1.5° in length visually."

Triton Watch Program

Backyard observers with medium- or large-aperture telescopes have an opportunity to help scientists get the most out of the *Voyager* encounter with Neptune in 1989. A team of astronomers in California is organizing a network for observations of Neptune's moon Triton. Careful observations of occultations of stars by Triton could help determine Triton's diameter, orbital characteristics, and possibly even the moon's atmospheric nature. Because Triton is large and has a significant gravitational influence on the Neptunian system, information supplied by backyard observers could help NASA make last-minute adjustments to *Voyager*'s trajectory. For information on how you can help with this observing program, write John Hewitt, Triton Occultation Watch, 418 Boynton Avenue, Berkeley, CA 94707.



Comet Bradfield displayed fine details in backyard telescopes during the last three months of 1987. Joseph Romero of San Antonio, Texas, sketched this view of the comet with a 2.4-inch refractor on October 26, 1987.

Capturing Colors of the Stars

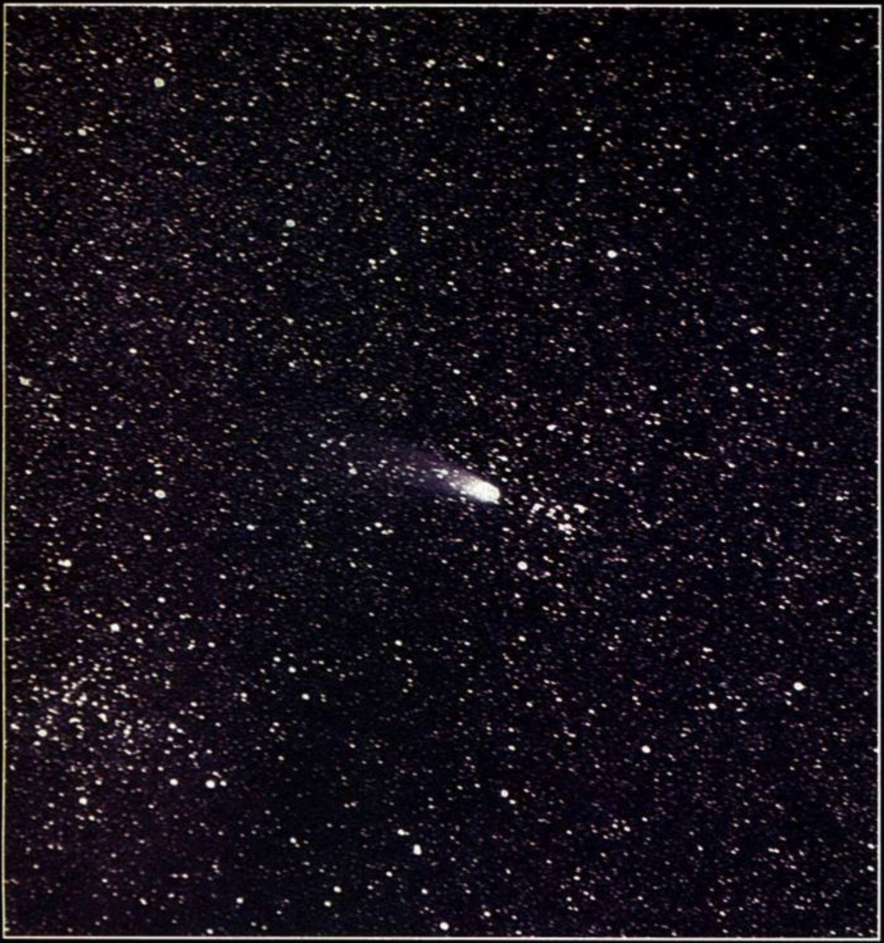
Color films record a wide spectrum of star colors from blue to red, but often the colors these films portray are subtle. Astrophotographers Brendan Bouffler and Richard Hellestrand of New South Wales, Australia, have experimented with an unusual method of recording star colors dramatically. Rather than making a straight, guided exposure of a starfield, the Australians allow the stars in their photographs to trail through the frame and systematically defocus the images once every minute. This smears out the light from stars into a larger area on the film, thereby showing star colors better than an ordinary photo could.

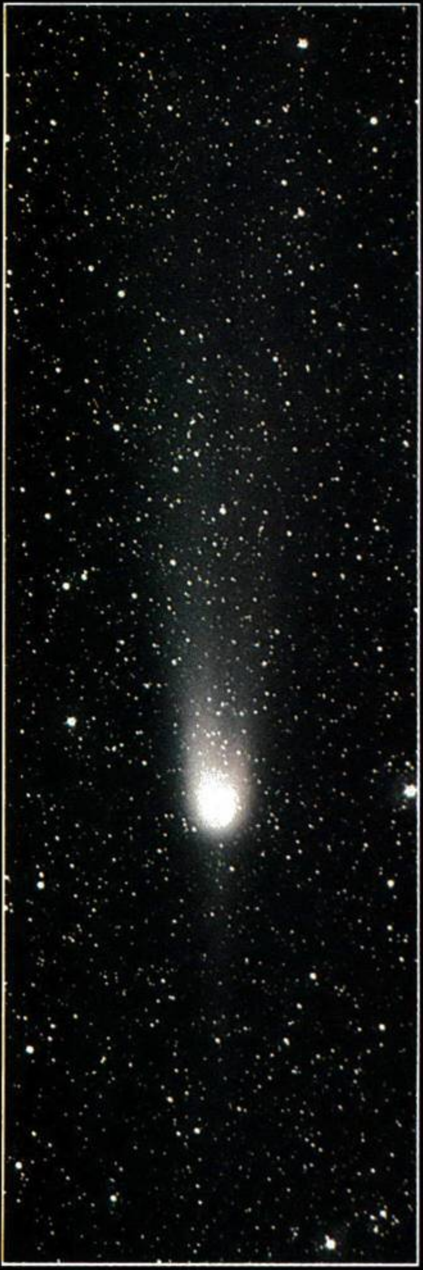
Bouffler and Hellestrand explained their technique: "What we need is a single shot with multiple images, one of which pertains to the right exposure for each star. We borrowed our method from David Malin of the Anglo-Australian Observatory, who has used it for some time. We simply change the focusing adjustments at regular intervals, usually of about one minute. Specifically, we set up our camera on a tripod with a standard 50mm lens, lined up on the field to be photographed, and locked the shutter open. Initially we set the focus on infinity and every minute we placed a piece of black cardboard over the lens and changed the focusing by one tenth of the focuser's total movement. We continued this until the focuser reached the end of its travel.

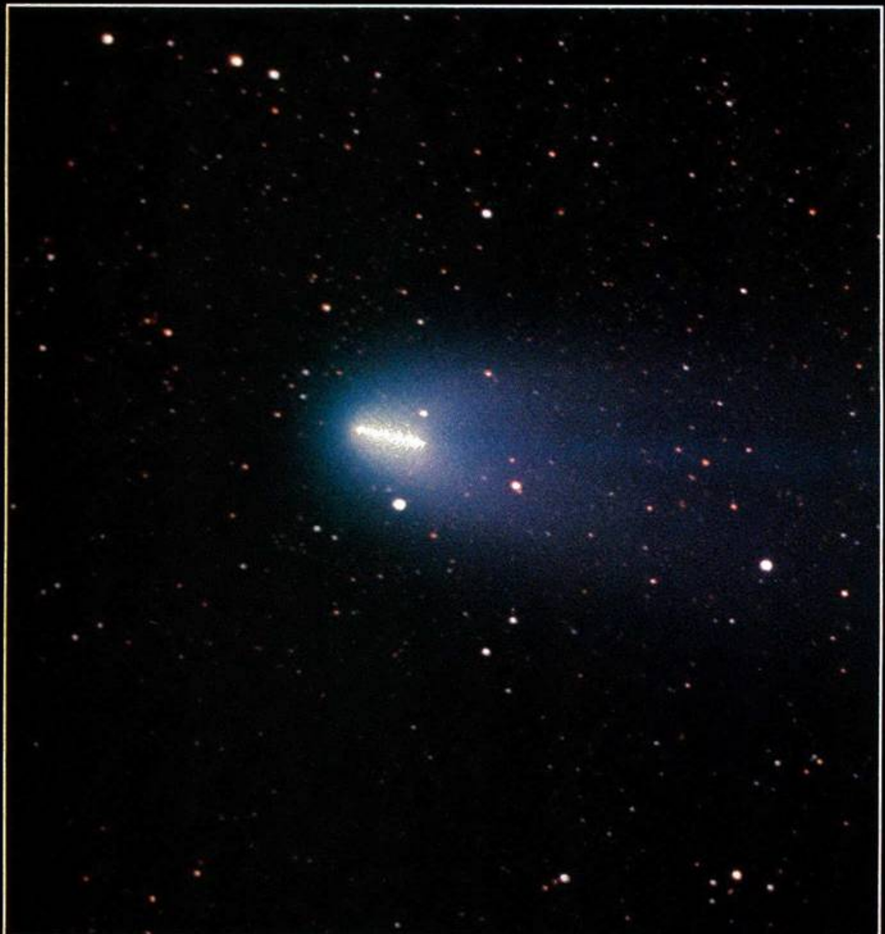
"At first we guessed on the focusing, but we overcame this problem by wrapping a strip of black electrical tape around the focus ring with the adjustment intervals clearly marked in white ink. This allowed us to see the adjustments in the dark."

The Australians experimented for several weeks with different combinations of films and f/ratios. "We found a very successful pairing to be shooting the pictures at f/2 with Fujichrome 400. Even though the red sensitivity of this film was cut back slightly by the manufacturer one year ago, it is still a very good film for astrophotography and we use it all the time. The 400 ISO rating gives a good compromise between speed and grain."

According to Bouffler and Hellestrand, they produce these defocused portraits of the sky because "it is one way of turning those boring old astrophotos of the constellations into exciting works of art you will be proud to show your family and



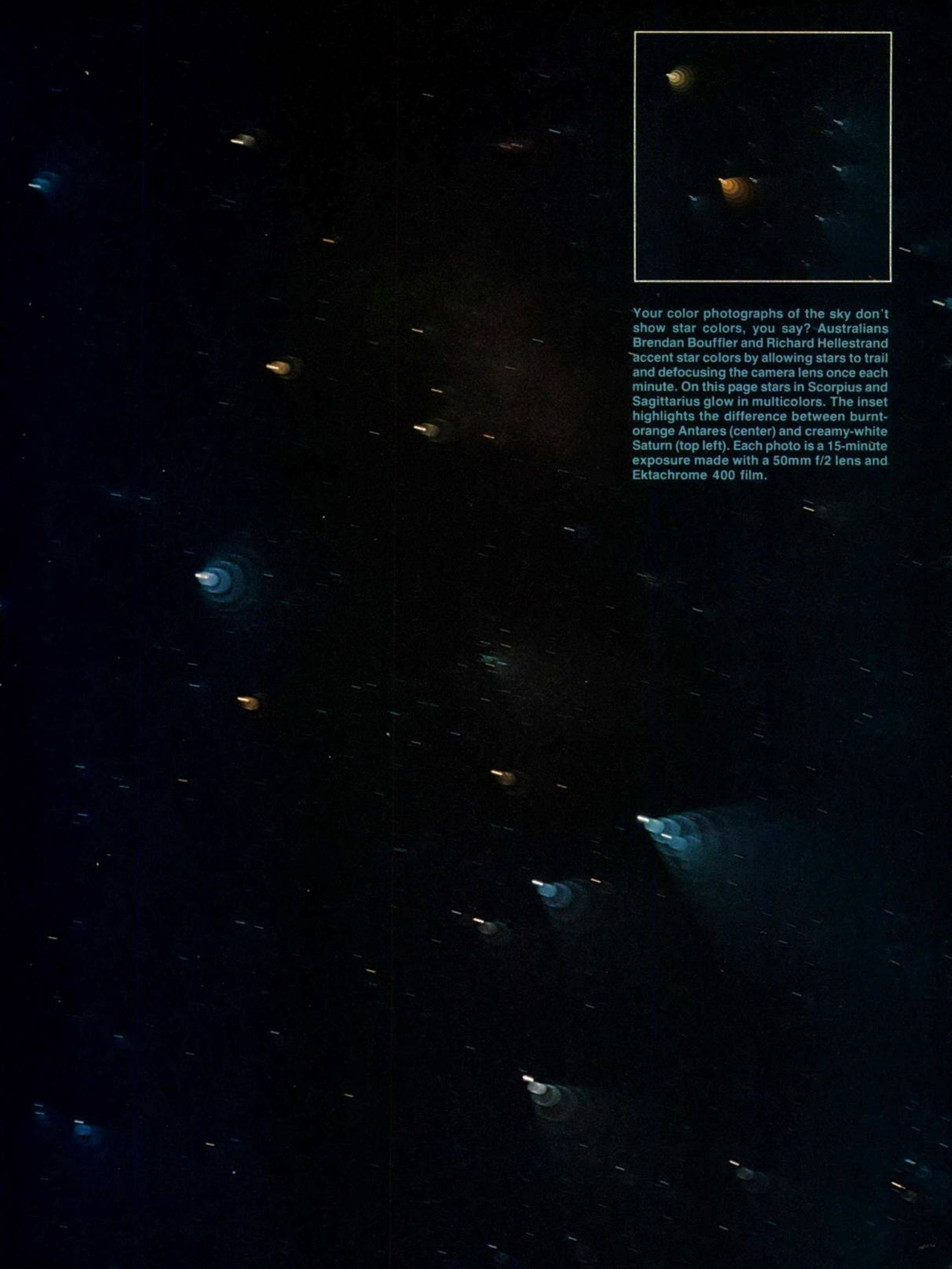




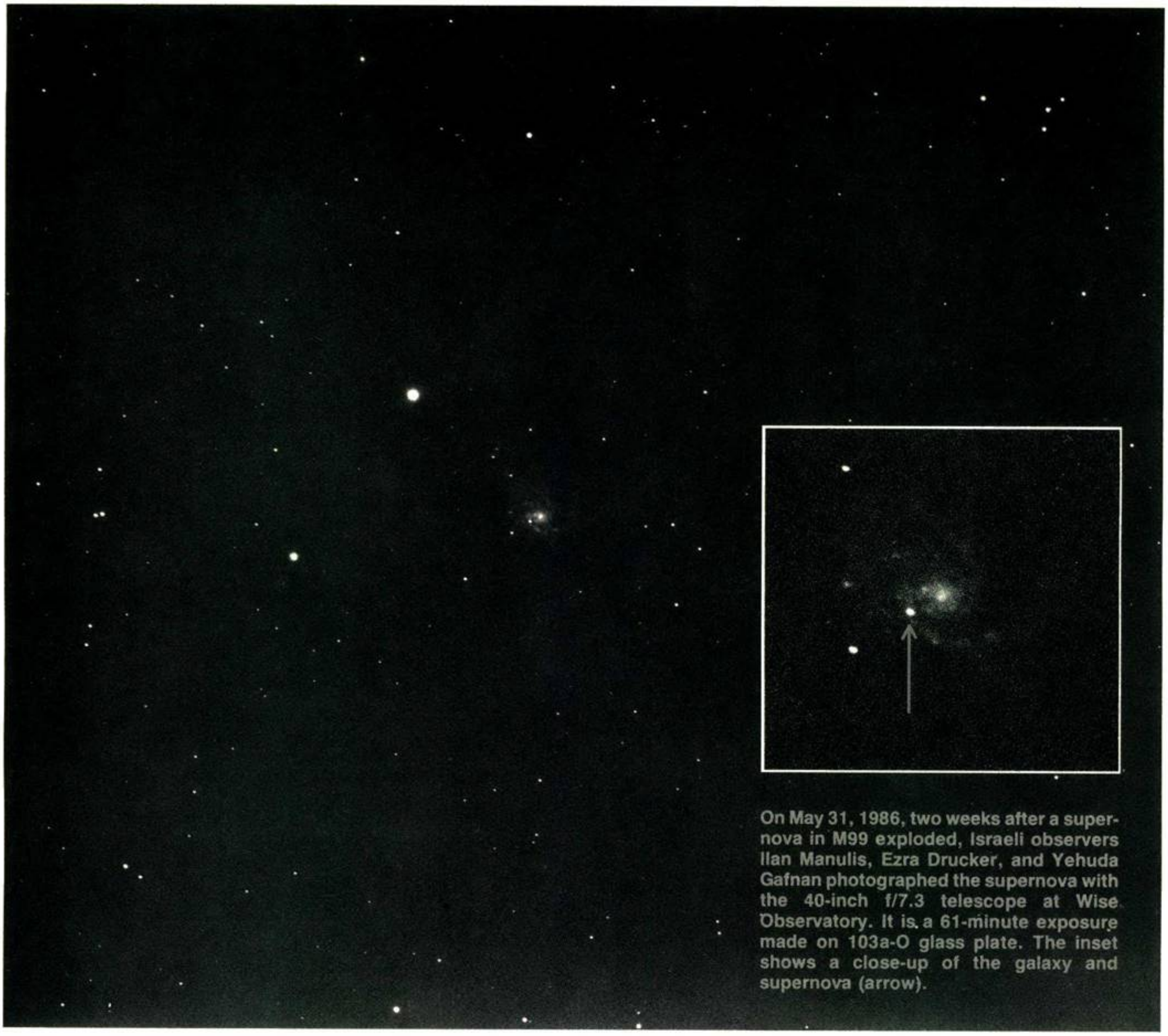
Top left: In mid-November Bradfield passed between the bright open clusters NGC 6633 (just right of the comet) and IC 4756 (lower left). Martin C. Germano of Thousand Oaks, California, photographed the event on November 14, 1987, with a 135mm f/4 lens and hypersensitized Tech Pan film. He guided the 25-minute exposure on the comet.

Left: On November 12, Michael Stecker of Los Angeles made this close-up shot of the comet's ion tail (the thin blue streak) and its wide, fan-shaped dust tail.

Above: During the last week of December Comet Bradfield developed a prominent antitail, a stream of material apparently pointing toward the Sun. Chris Schur photographed the comet and its antitail on December 20, 1987, with an 8-inch f/1.5 Schmidt camera and hypersensitized Tech Pan film. He used a yellow filter for the 10-minute exposure.



Your color photographs of the sky don't show star colors, you say? Australians Brendan Bouffler and Richard Hellestrand accent star colors by allowing stars to trail and defocusing the camera lens once each minute. On this page stars in Scorpius and Sagittarius glow in multicolors. The inset highlights the difference between burnt-orange Antares (center) and creamy-white Saturn (top left). Each photo is a 15-minute exposure made with a 50mm f/2 lens and Ektachrome 400 film.



On May 31, 1986, two weeks after a supernova in M99 exploded, Israeli observers Ilan Manulis, Ezra Drucker, and Yehuda Gafnan photographed the supernova with the 40-inch f/7.3 telescope at Wise Observatory. It is a 61-minute exposure made on 103a-O glass plate. The inset shows a close-up of the galaxy and supernova (arrow).

friends. Producing these star color shots has given us many hours of fun under the stars, and it even works well in the Northern Hemisphere, where everything is upside-down!"

Photographing a Supernova

You're at a professional observatory, the sky is clear, and you've just found out that a newly discovered supernova is glimmering somewhere in the spiral arms of galaxy M99. What do you do? Israeli reader Ilan Manulis had this experience on May 31, 1986, and shares his story of that night of adventure.

"We were at the Wise Observatory at Mitzpe-Ramon, Israel, engaged in photographing and making astrometric measurements of Comet Halley. My colleagues Ezra Drucker and Yehuda Gafnan and I were part of a continuing effort to watch Halley by a small group of Israeli amateurs supported by the department of astrophysics at Tel Aviv University.

"On the second day of our visit I picked up a telegram sent from the International Astronomical Union and saw to my surprise that a supernova had been discovered. 'Ah, another one of those 18th-magnitude objects,' I thought. Not this time. This supernova shone at 14th magnitude at its discovery, and the telegram took only a few days to reach us rather than the usual fortnight. Maybe the supernova was bright by now.

"Later that night I checked the position of M99 as Halley sank slowly into the west. We decided to try to photograph the galaxy and its temporary visitor. After all, if not the supernova itself, at least we would have a nice photograph of the galaxy. While Ezra made the 1-hour exposure, Yehuda and I sat down and plotted the position of the supernova relative to the galaxy's nucleus on the back of an envelope.

"With envelope in hand we entered the darkroom thrilled and anxious. Did we get it? Was Ezra tracking properly, or will the stars be trailed? How was the seeing during the exposure? How bright will the supernova be? Will we be able to identify it? We took the plate out of the chemicals and placed it, still dripping wet, on the illuminated table. Ezra said, 'There's nothing in here!' But wait, there was a galaxy in the center and I looked closely and saw a minute star in one of the spiral arms. We placed the envelope beside the plate and confirmed we had captured the light from a distant supernova after all.

"Of course we knew we did not discover the supernova, but for us photographing it and discovering the object on our plate gave us almost as much exhilaration. It was an unforgettable night."

— *David J. Eicher*

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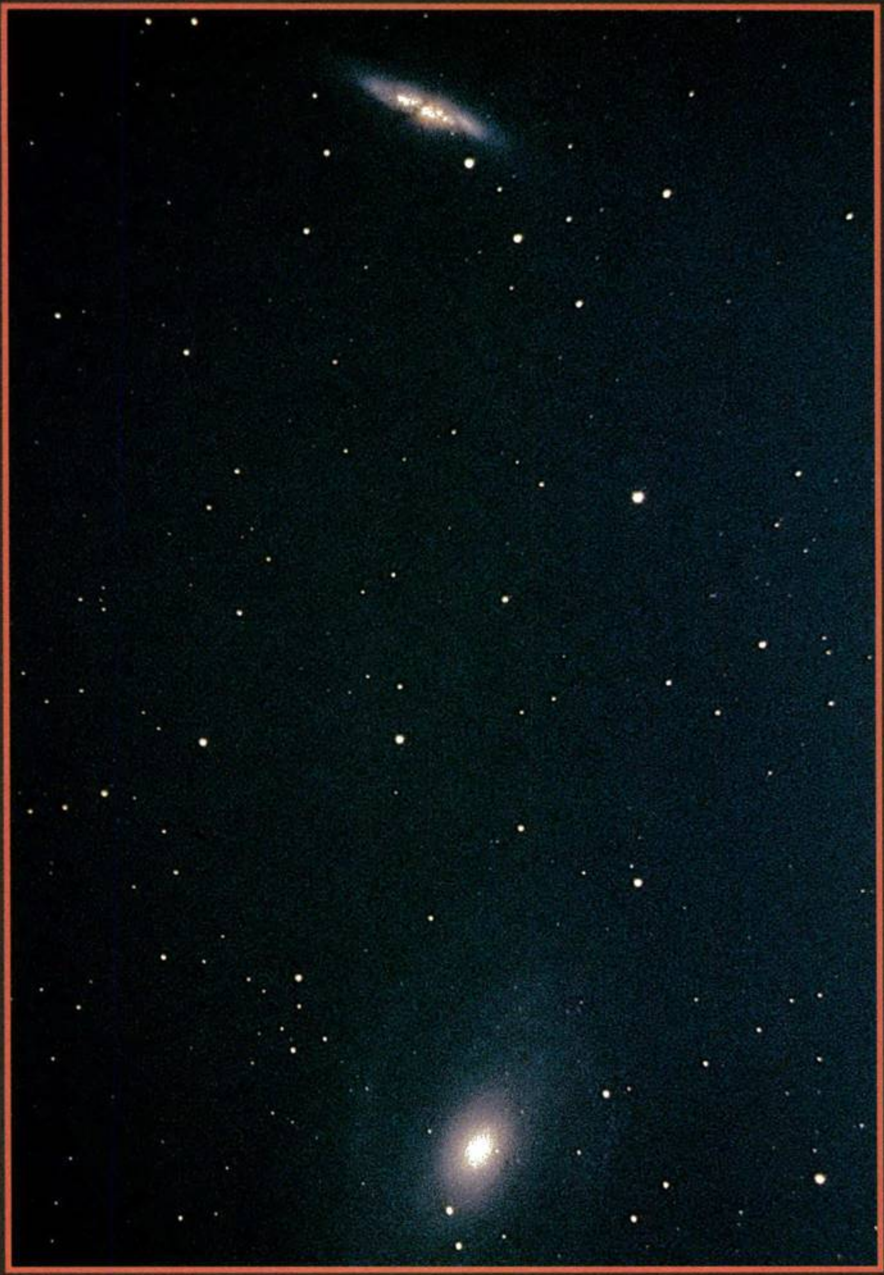
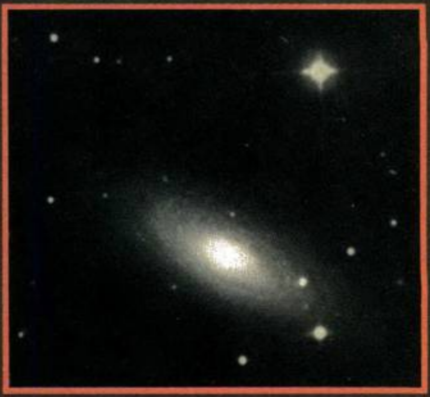
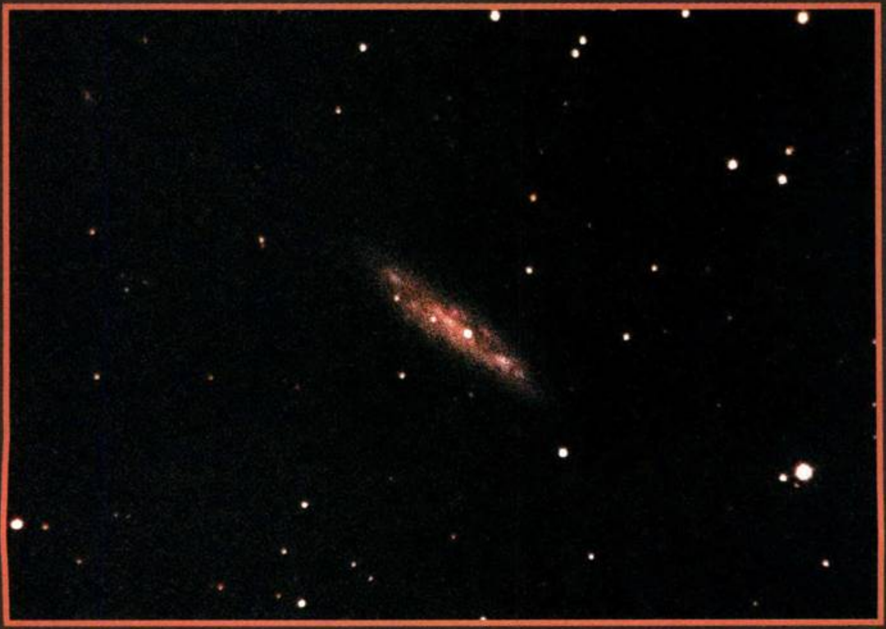






Above top: Just over 1° southwest of M81 is the low surface brightness galaxy NGC 2976, a smear of light in backyard telescopes. Photo by Jack Newton.

Above center: NGC 2841 shows a bright oval core and smooth, tightly wound arms. Photo by K. Alexander Brownlee.

Above: M109 is a low surface brightness barred spiral with a bright, round, nuclear bulge. Photo by Mace Hooley.

Top left: Separated by 38′, the bright galaxies M82 (top) and M81 form an impressive pair in northwestern Ursa Major. Photo by Jack Newton.

Left: Located 1° northwest of the famous Owl Nebula, galaxy M108 appears as a thin, mottled streak of light. Photo by Gary Hug.

Galaxies in the Great Bear

Above: NGC 3079 appears as a sliver of gray light in small telescopes. Photo by Martin C. Germano.

If you're new to backyard astronomy, one of the greatest parts of the hobby awaits you — the first time you observe a group of galaxies. Standing out underneath a crisp, cool, springtime sky with stars twinkling overhead and a soft breeze gently stirring the treetops, you really feel one with nature. Some backyard stargazers think that witnessing the graceful, spiral arms of a distant galaxy is the pinnacle of discovering your place in the grand scheme of the universe.

Twice a year the sky "opens up" and we see deep into the universe. During the summer and winter the star-studded Milky Way dominates the evening sky, blocking the view of the galaxies beyond. But in spring and autumn we look below and above the galactic plane out into the vast realm of deep space. Ursa Major, the Great Bear, is one of the richest areas of sky for galaxy hunters. Suspended in and around the familiar asterism called the Big Dipper, the brightest part of Ursa Major, dozens of galaxies await discovery with backyard telescopes. Twenty-seven of these galaxies are bright enough and large enough to show detail in backyard telescopes, which gives you a chance to observe the nuclei and spiral arms of distant islands of stars and dust.

Several bright galaxies lie inside the Big Dipper. The best of these is **M108** (NGC 3556), an edge-on Sc-type spiral that lies 2° southeast of Beta (*β*) Ursae Majoris. (Sc-type spirals have open, loosely wound arms that contain clumpy regions of star formation.) M108 is large and bright enough that it is visible in large finder scopes and large binoculars on dark nights and appears as a spot of nebulosity. A telescope shows this galaxy as a sliver of gray-green light measuring 8′ across and glowing at magnitude 10.1 with a faint foreground star superimposed near the galaxy's center. The surface brightness of M108 is 13.8, which means that one square arcminute of M108 glows with the brightness of a 13.8-magnitude star.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

Different size telescopes portray the universe in very different ways. For example, a 4-inch scope shows M108 merely as a thin streak of light. At high power on moonless nights, however, a 6-inch scope shows subtle mottling across the surface of this galaxy; the mottling represents patches of dark matter along the galaxy's disk. Large backyard telescopes, those bigger than 14 inches in aperture, show this mottling and an irregular, slightly curved shape in M108 under average transparency. The bright, splendid planetary nebula M97, the Owl Nebula, lies 1° southeast of M108 and may be seen within the same low-power field.

Nearly 3° southeast of M108 is the Sc-type galaxy **NGC 3631**. This object is physically similar to M108 but lies almost twice as far away. NGC 3631 lies at a distance of 17 megaparsecs, compared with M108's distance of 10 megaparsecs. The bright disk component of each galaxy spans about 25 kiloparsecs. Yet viewed from Earth, NGC 3631 appears nearly as bright as M108. Why? NGC 3631 must be intrinsically far more luminous than its neighbor.

NGC 3631 is tipped only slightly from a face-on angle so that it measures 4.6′ by 4.1′. The galaxy's total light output equals that of a magnitude 10.4 star, and its average surface brightness in 14.1. A 6-inch scope shows NGC 3631 as a circular glow with a stellar nucleus. A 10-inch scope, however, shows a 4′-diameter halo of faint nebulosity surrounding a bright disk of light and a sharp, stellar nucleus.

In the center of the Dipper's bowl, forming a right triangle with Alpha (*α*) and Beta Ursae Majoris, is the Sc-type spiral **NGC 3642**. Slightly fainter than NGC 3631, this galaxy is nevertheless easily visible in small scopes. In a 6-inch instrument NGC 3642 appears as a faint smear of light measuring 5′ by 4′ with a condensed, ball-like nucleus.

The beautiful barred spiral galaxy **M109** (NGC 3992) lies 40′ southeast of Gamma (*γ*) Ursae Majoris, the star marking the southeastern corner of the bowl. Barred spirals are characterized by a broad bar of material extending through the galaxy's nucleus. M109 measures 7.6′ by 4.9′ across and glows at magnitude 9.8, which makes it easily visible as an oval patch of light in a 3-inch scope. At low power, backyard scopes show this galaxy in the same field as the bright star, which makes observing detail in the galaxy difficult. Once you locate M109, switch to moderately high powers so you eliminate the distracting glare from Gamma Ursae

Majoris.

A 10-inch scope shows some detail in M109, including a large glowing halo of light around a bright, almost stellar core. On nights when the seeing is steady, a 13th-magnitude star is visible just off the galaxy's northern edge. A 17.5-inch telescope under a dark sky shows the subtle barred spiral structure of M109, especially if you use averted vision. Also visible in a 17.5-inch scope is a small, dark patch near the galaxy's core and two bright patches in the spiral arms.

Three degrees northwest of Alpha Ursae Majoris is the bright barred spiral **NGC 3359**. Similar in size to NGC 3953 and only slightly dimmer, this galaxy is easily visible as a nebulous oval patch in a 3-inch telescope. Six-inch telescopes show a tiny, almost starlike core immersed in a uniformly bright envelope of hazy light.

Ten degrees northwest of Alpha Ursae Majoris lies one of the great galaxy groups in the sky, the M81 group. This small cloud of galaxies lies at a distance of 2.1 megaparsecs and measures some 1.8 by 0.9 megaparsecs in extent. Contained within these boundaries are the bright galaxies M81, M82, NGC 2976, and possibly NGC 3077 (its gravitational bond to the others is probable but not certain).

M81 (NGC 3031) is a dazzling sight in any telescope. Shining at magnitude 6.9 and spanning 25.7′ by 14.1′, M81 is visible in finder scopes and binoculars as a nebulous smudge and can be seen as a large patch of green-gray light in a 2-inch telescope. Just 37′ north of M81 and visible in the same low-power field is the peculiar galaxy **M82** (NGC 3034), an edge-on system with a high surface brightness. Viewed with a 2-inch telescope, M82 appears as a bright streak of light only slightly wider in its central bulge than at its ends. M82 glows at magnitude 8.4 and measures 11.2′ by 4.6′ across.

With a 6-inch telescope at 35x you can see both galaxies at opposite ends of the same field of view. M81 appears as a bright, oval-shaped nebula with a very faint outer halo of light, whereas M82 looks like a spindle of gray light with a starlike nucleus. Large backyard telescopes transform the views of M81 and M82 by showing intricately detailed galaxies. A 17.5-inch scope at 142x reveals the delicate spiral pattern in M81 and dark, irregular knots of dust splashed across the disk of M82.

NGC 2976 and NGC 3077, related gravitationally to the M81/M82 pair, lie within the immediate area. **NGC 2976** lies 2° southwest of M81; it is a magnitude 10.2 spiral that measures 4.9′ by 2.5′ in extent. **NGC 3077** can be found 1° southeast of M81 and is a magnitude 9.9 elliptical system spanning 4.6′ by 3.6′.

After looking at NGC 3077, move your telescope 3° east and 30′ south. If you're observing with a 6-inch or larger scope, you may see a faint nebulosity about 10′ across centered in your field of view. This is **IC 2574**, a low surface brightness spiral with a magnitude of 10.6. This object is relatively close — only 2.5 megaparsecs away — but it is intrinsically small and dim and therefore hard to observe on anything less than perfectly dark nights.

One of the Great Bear's most impressive spirals is **NGC 2841**, located 2.5° southwest of the bright star Theta (θ) Ursae Majoris and in the same field as the double star designated 37 Lyncis. An Sb-type spiral, NGC 2841 glows at magnitude 9.3 and measures 8.1′ by 3.8′. The galaxy has a high surface brightness and is visible as an elongated oval in a 3-inch scope. A 6-inch telescope shows a bright, oval disk surrounded by a much dimmer haze of lower surface brightness nebulosity.

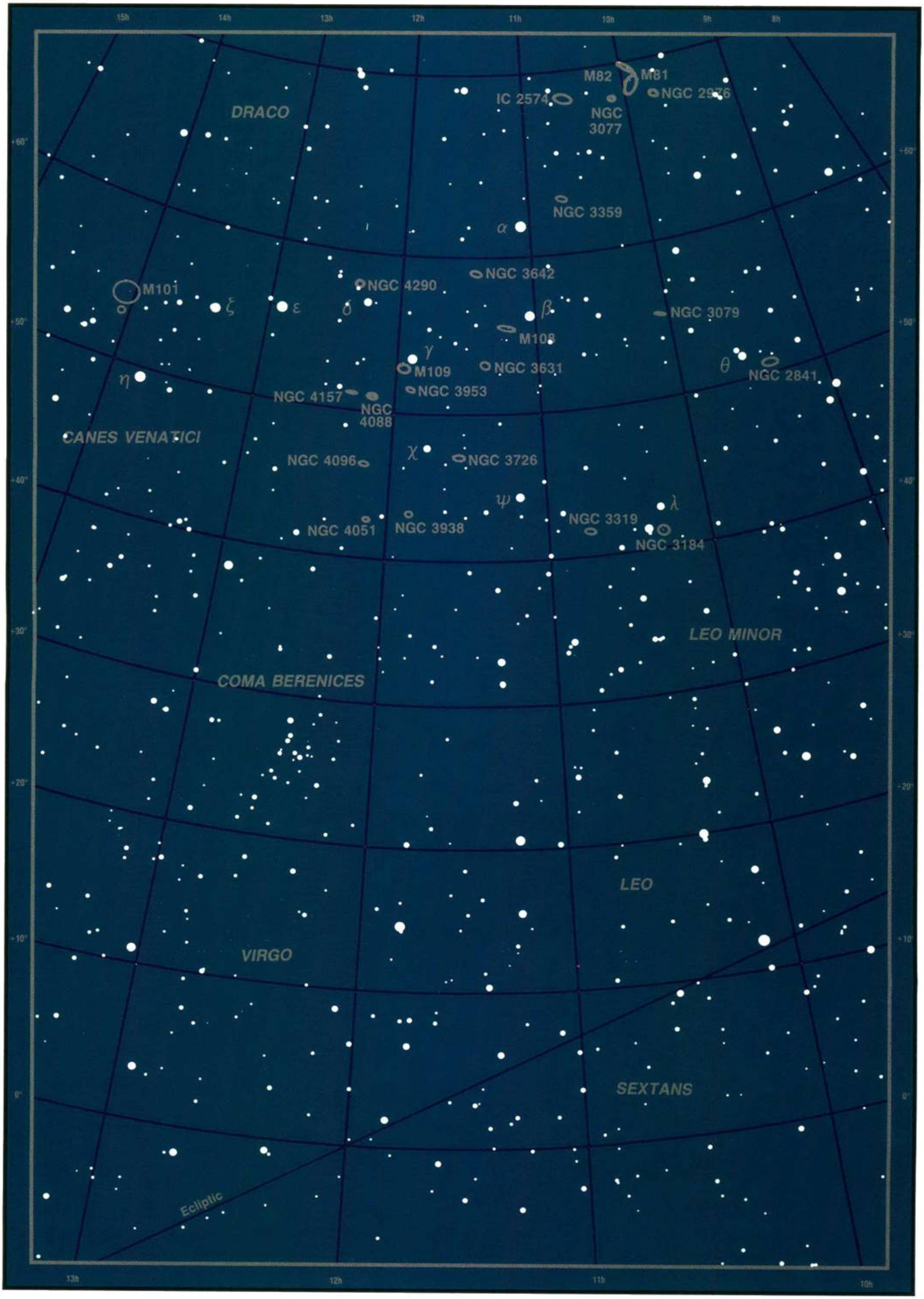
In the far northeastern reaches of the Great Bear, almost on the border of Draco, lies a pair of bright galaxies. **M101** (NGC 5457) is a face-on spiral covering 26.9′ by 26.3′ and glowing at magnitude 7.7. To find this galaxy, start at the double star Mizar (Zeta [ζ] Ursae Majoris) and star hop east along a row of four bright stars. When you reach the end star, move your scope 2° northeast and you'll be centered on M101. The core of M101 is visible in small scopes even on average nights, but the galaxy's arms have a low surface brightness and require a dark sky to be seen. Use a 6-inch or larger scope, a wide-field eyepiece, and observe on a moonless, transparent night for best results. **NGC 5474**, a satellite galaxy of M101, lies 1° to the southeast. This little galaxy measures 4.5′ by 4.2′ across and glows at 11th magnitude.

— David J. Eicher

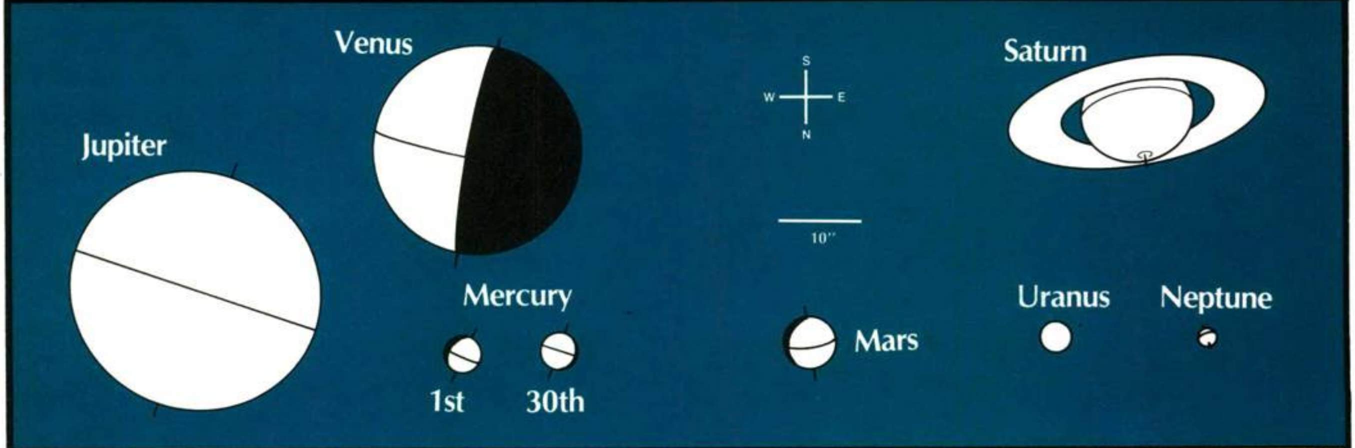
Ursa Major's Bright Galaxies

Object	M#	Type	R.A. (2000)	Dec.	Mag.	SB	Size	Distance	Diameter
NGC 2841		Sb$^-$	9h22.0m	+50°58′	9.3	13.7	8.1′ x 3.8′	9 Mpc	20 kpc
NGC 2976		Sc pec	9h47.3m	+67°55′	10.2	13.4	4.9′ x 2.5′	2.3 Mpc	3 kpc
NGC 3031	M81	Sb	9h55.6m	+69°04′	6.9	14.0	25.7′ x 14.1′	3.4 Mpc	30 kpc
NGC 3034	M82	Pec	9h55.8m	+69°41′	8.4	13.4	11.2′ x 4.6′	3.4 Mpc	12 kpc
NGC 3079		Sb	10h02.0m	+55°41′	10.6	13.8	7.6′ x 1.7′	16 Mpc	35 kpc
NGC 3077		E2 pec	10h03.3m	+68°44′	9.9	13.5	4.6′ x 3.6′	2.0 Mpc	2.5 kpc
NGC 3184		Sc	10h18.3m	+41°25′	9.8	14.4	6.9′ x 6.8′	7.9 Mpc?	15 kpc?
IC 2574		S$^+$	10h28.4m	+68°25′	10.6	15.5	12.3′ x 5.9′	2.5 Mpc	9 kpc
NGC 3319		S(B)c	10h39.2m	+41°41′	11.3	15.2	6.8′ x 3.9′	10 Mpc	20 kpc
NGC 3359		S(B)c	10h46.6m	+63°13′	10.5	14.5	6.8′ x 4.3′	15 Mpc	30 kpc
NGC 3556	M108	Sc	11h11.5m	+55°40′	10.1	13.8	8.3′ x 2.5′	10 Mpc	25 kpc
NGC 3631		Sc	11h21.0m	+53°10′	10.4	14.1	4.6′ x 4.1′	17 Mpc	25 kpc
NGC 3642		Sc	11h22.3m	+59°05′	11.1	15.1	5.8′ x 4.9′	23 Mpc	40 kpc
NGC 3726		Sc	11h33.3m	+47°02′	10.4	14.4	6.0′ x 4.5′	11 Mpc?	20 kpc?
NGC 3938		Sc	11h52.8m	+44°07′	10.4	14.3	5.4′ x 4.9′	11 Mpc	17 kpc
NGC 3953		Sb$^+$	11h53.8m	+52°20′	10.1	14.0	6.6′ x 3.6′	14 Mpc	25 kpc
NGC 3992	M109	S(B)b$^+$	11h57.6m	+53°23′	9.8	14.4	7.6′ x 4.9′	15 Mpc	35 kpc
NGC 4051		Sc	12h03.2m	+44°32′	10.3	14.0	5.0′ x 4.0′	10 Mpc	15 kpc
NGC 4088		Sc	12h05.6m	+50°33′	10.5	13.8	5.8′ x 2.5′	11 Mpc	20 kpc
NGC 4096		Sc	12h06.0m	+47°29′	10.6	13.7	6.5′ x 2.0′	7.5 Mpc	15 kpc
NGC 4157		Sb$^+$	12h11.1m	+50°29′	11.7_B	14.1	6.9′ x 1.7′	12 Mpc?	25 kpc?
NGC 4290		SBb	12h20.8m	+58°06′	12.5_B	14.1	2.5′ x 1.9′	40 Mpc	30 kpc
NGC 5457	M101	Sc	14h03.2m	+54°21′	7.7	13.9	26.9′ x 26.3′	5.2 Mpc	40 kpc

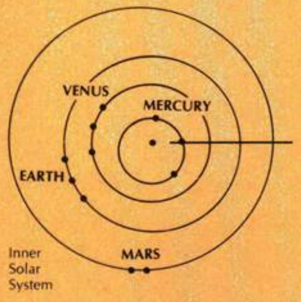
Object: Designation in NGC or IC. **M#:** Designation in Messier catalog. **Type:** Hubble classification. **R.A.** and **Dec.:** Coordinates for epoch 2000.0. **Mag.:** V magnitude of galaxy unless marked by subscript B, which denotes blue magnitude. **SB:** Mean surface brightness in magnitudes per square arcminute. **Size:** Angular size in arcminutes. **Distance:** Distance of galaxy in megaparsecs. **Diameter:** Linear diameter of galaxy in kiloparsecs.

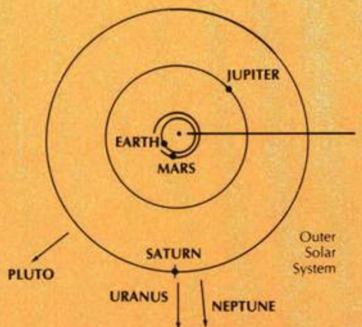

15h
14h
13h
12h
11h
10h
9h
8h
DRACO
M82
M81
IC 2574
NGC 2976
NGC 3077
NGC 3359
α
NGC 3642
NGC 4290
M101
ζ
ε
δ
β
NGC 3079
M108
γ
M109
NGC 3631
θ
NGC 2841
η
NGC 4157
NGC 4088
NGC 3953
CANES VENATICI
χ
NGC 4096
NGC 3726
ψ
λ
NGC 3319
NGC 3184
NGC 4051
NGC 3938
LEO MINOR
COMA BERENICES
LEO
VIRGO
SEXTANS
Ecliptic
+60°
+50°
+40°
+30°
+20°
+10°
0°
13h
12h
11h
10h

Planetary Data April 1988


Venus
Jupiter
S
W
E
N
10''
Saturn
Mercury
1st
30th
Mars
Uranus
Neptune

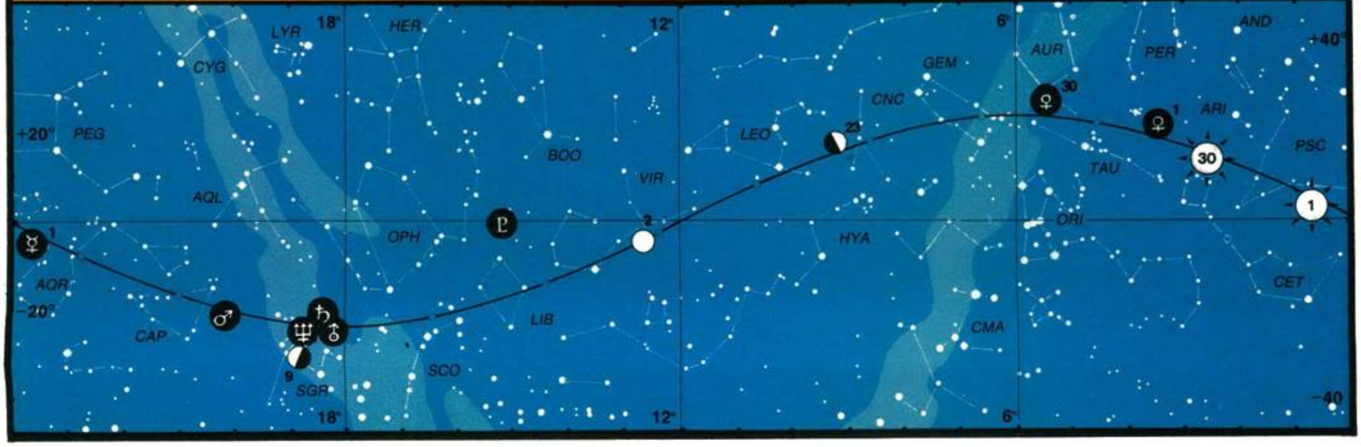
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.7	32.0′	—	0.999	—	—	11°29.3′	0h42.8m	4°36.4′
		15	−26.7	31.9′	—	1.003	—	—	25°14.8′	1h34.2m	9°49.7′
		30	−26.7	31.8′	—	1.007	—	—	39°52.4′	2h30.5m	14°49.6′
Mercury	☿	1	−0.4	5.4″	84%	1.239	0.429	306°00.0′	351°48.0′	23h39.6m	−4°47.4′
		15	−1.4	5.1″	98%	1.333	0.353	1°18.8′	19°18.4′	1h13.1m	6°16.7′
		30	−1.4	5.5″	90%	1.234	0.308	88°05.9′	50°40.8′	3h11.9m	19°01.5′
Venus	♀	1	−4.3	22.9″	52%	0.729	0.719	144°49.0′	56°27.0′	3h37.8m	22°37.6′
		15	−4.4	26.9″	44%	0.620	0.719	167°33.5′	70°32.5′	4h33.8m	25°57.0′
		30	−4.5	33.1″	33%	0.504	0.721	191°50.7′	82°13.6′	5h25.4m	27°36.3′
Mars	♂	10	0.6	7.2″	87%	1.306	1.476	260°25.1′	302°14.9′	20h19.1m	−20°42.6′
		20	0.5	7.6″	87%	1.226	1.463	266°01.6′	308°56.9′	20h47.0m	−19°17.6′
Jupiter	♃	15	−2.0	33.0″	100%	5.946	4.975	41°02.6′	38°34.7′	2h26.0m	13°28.3′
Saturn	♄	15	0.4	17.2″	100%	9.613	10.043	267°15.1′	272°41.0′	18h11.7m	−22°15.9′
Uranus	⛢	15	5.6	3.7″	100%	18.834	19.268	268°16.8′	271°00.8′	18h05.1m	−23°38.0′
Neptune	♆	15	7.9	2.2″	100%	29.950	30.226	278°21.2′	280°15.3′	18h44.7m	−22°03.7′
Pluto	♇	15	13.7	0.1″	100%	28.743	29.668	221°04.4′	221°46.0′	14h57.6m	0°27.7′


VENUS
MERCURY
EARTH
MARS
Inner Solar System


JUPITER
EARTH
MARS
PLUTO
SATURN
URANUS
NEPTUNE
Outer Solar System

Moon Data

Full Moon . . . . April 2 at 9h21m
Last Quarter . . . . April 9 at 19h21m
New Moon . . . . April 16 at 21h00m
First Quarter . . . . April 23 at 22h32m
Full Moon . . . . May 1 at 23h41m
Last Quarter . . . . May 9 at 1h23m
Perigee: April 13 at 22h49m . . . 364,311 km
Apogee: April 25 at 18h34m . . . 404,510 km


LYR
18°
HER
12°
6°
AUR
PER
AND
+40°
CYG
GEM
CNC
30
ARI
1
+20°
PEG
LEO
23
30
PSC
BOO
TAU
VIR
AQL
2
1
ORI
OPH
HYA
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−20°
CET
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CAP
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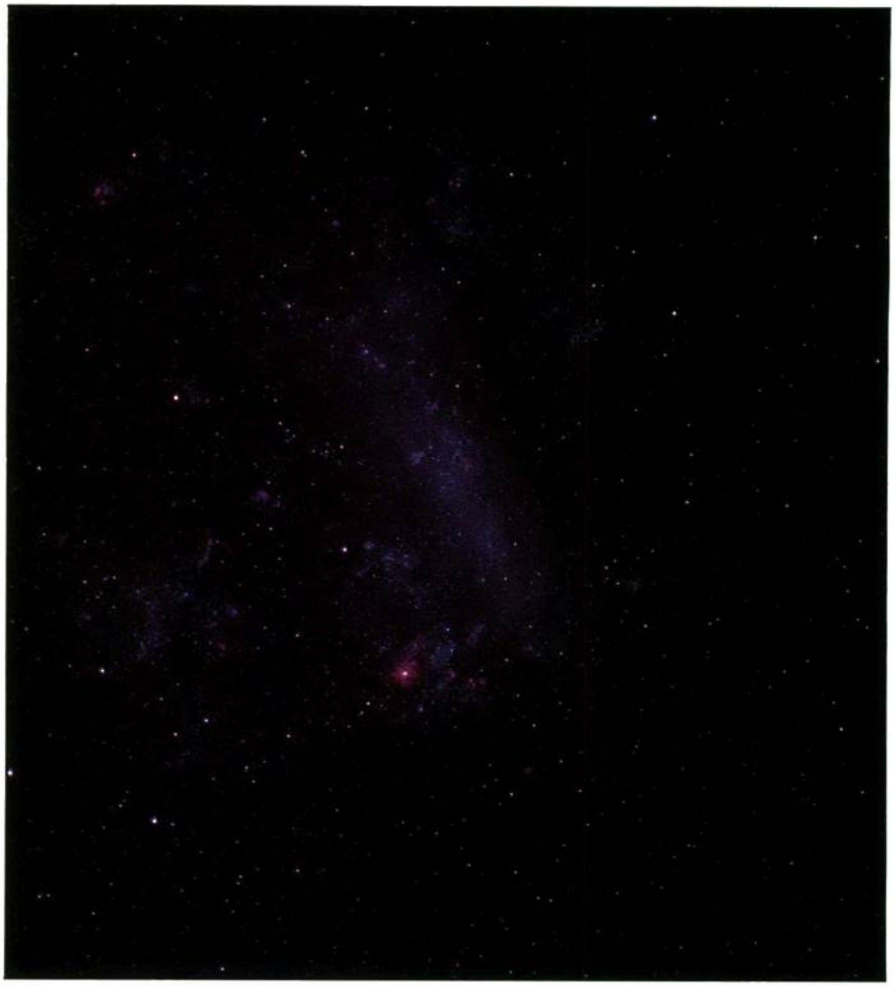
9
SCO
SGR
18°
12°
6°
−40



Right: Delight of the southern sky, the Large Magellanic Cloud glows eerily in this photograph made with a 300mm f/4 lens. The bright pink spot near the cloud's southern end is the Tarantula Nebula. Photo by Barney Magrath, who used a 25-minute exposure on hypersensitized Fujichrome 100 film.

Planets

Mercury

Because Mercury is in superior conjunction with the Sun on April 20, it will be hidden in the Sun's glare most of the month. Only in the last week of April will Mercury emerge low in the southwest, where you can spot it with difficulty about 3° above the horizon, forty-five minutes after sunset. (An unobstructed view toward the southwest is a must, however.)

Seen in your telescope, −1.6-magnitude Mercury will be a shimmering dot of light 5.3″ across. Bad seeing and refraction at so low an elevation will surround the disk with a nimbus of false color and scattered light. The planet itself will look featureless, ivory-white, and almost completely round.

Venus

In the first week of April Venus will pass a couple of degrees south of the Pleiades, and your best views will come with binoculars or a finder scope. On April 3, Venus reaches greatest eastern elongation from the Sun — its highest elevation in the western evening sky and best visibility. Shining at magnitude −4.4, Venus dominates the scene until it sets about four hours after the Sun.

In the next two-and-a-half months there will be exciting changes in the telescopic appearance of Venus. While Venus' white cloud tops will remain as featureless as ever, Venus' apparent size will grow by 50 percent (from 22″ across to 33″) during April, and its disk will become distinctly crescent. If glare gives Venus a fuzzy, unsharp look in your eyepiece, try viewing early in twilight when the sky is still fairly bright.

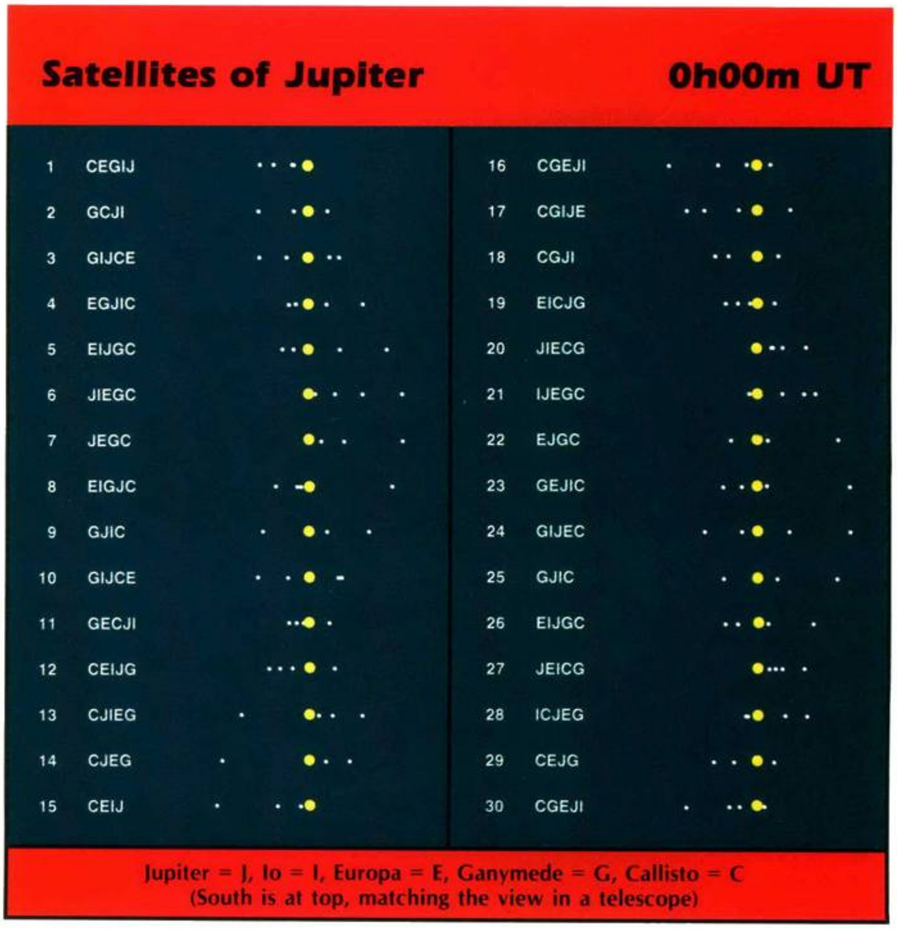
Mars

Rising around 3 a.m. and shining amber-white at magnitude 0.6, Mars is prominent in the predawn hours. Its northern hemisphere reaches its autumnal equinox on April 18, when the Martian disk will have a diameter of 7.5″. By opposition on September 28, it will triple in apparent size.

Unless your scope is large or has a long focal length, discerning markings on Mars' disk will be difficult. But by now everyone with a telescope should be watching the Red Planet at every opportunity. This is the best Martian apparition for almost twenty years, and nothing helps your eye see the elusive surface features better than repeated viewing.

Minor Planets

1 Ceres (magnitude 8.9) will be difficult to observe because it lies in central



Aquarius and rises after morning twilight has begun. Its positions:

1st: 22h37m59s, −16°46.5′
10th: 22h50m43s, −15°49.1′
20th: 23h04m22s, −14°48.2′
30th: 23h17m24s, −13°51.5′

2 Pallas (10.2) is moving northeast in Delphinus, where it passes 22′ north of 4.0-magnitude Epsilon (ε) Delphini on April 16. (On the 13th, it passes only a couple arcminutes north of the 7th-magnitude triple star h 269; use chart 208 or 209 of *Uranometria 2000.0.*) Pallas' positions:

1st: 20h21m00s, 9°47.9′
10th: 20h28m30s, 10°53.4′
20th: 20h35m40s, 12°07.8′
30th: 20h41m28s, 13°22.0′

Pallas is an object for the wee hours because it rises about 2 a.m. local daylight time.

3 Juno (9.5) has a slow eastward motion among the stars in the tail of Cetus. Its positions:

1st: 2h07m37s, 5°28.3′
10th: 2h27m47s, 6°58.0′
20th: 2h50m33s, 8°31.6′
30th: 3h13m42s, 9°57.2′

Start looking for Juno as the sky darkens after sunset; the asteroid will set around 8 p.m. local daylight time.

4 Vesta (7.7) moves slowly eastward out of Gemini into Cancer during April. Its positions:

1st: 7h52m48s, 25°58.9′
10th: 7h59m34s, 25°41.0′
20th: 8h09m11s, 25°13.0′
30th: 8h20m39s, 24°36.6′

Vesta sets around 2:30 a.m. local daylight time.

11 Parthenope (9.9) lies in Virgo, where it passes about 2° south of 3rd-magnitude Zeta (ζ) Virginis on the 1st, and is at opposition on April 12. Its positions:

1st: 13h34m35s, −2°09.7′
10th: 13h26m52s, −1°13.6′
20th: 13h17m56s, −0°16.2′
30th: 13h09m48s, 0°27.0′

On the celestial equator and at opposition around mid-month, Parthenope will be visible from dusk till dawn.

To locate a minor planet, photocopy the appropriate chart from a good star atlas (*Uranometria 2000.0*, for example), plot the object's dated positions lightly in pencil, and sketch a smooth curve linking the points. (Positions are for 0h UT in epoch 2000.0 coordinates.) Then observe the starfield at low magnification and photograph or plot by hand what you see. Recheck the field a night or two later; the "star" that moved is the minor planet.

Jupiter

You can observe Jupiter for perhaps the first half of April, but sometime soon after the 15th, Jupiter will vanish into the evening twilight. On the 1st, Jupiter is 33″ across and at magnitude −2.0, but bad seeing at Jupiter's low elevation will prevent crisp views in a telescope. Jupiter will reappear in the morning sky late next month, rising shortly before the Sun.

Above: One of the brightest face-on galaxies in the sky, M51 in Canes Venatici displays its graceful spiral pattern in this 40-minute exposure made during the 1987 Riverside Telescope Makers Conference. Bob Luffel used a 14-inch SCT at f/7 and hypersensitized Konica SR 400 film.

Opposite page: Christian Arsidi's high-resolution photograph of Copernicus nets this month's $100 "Best Astrophoto" award. To capture fine detail on the lunar surface surrounding Copernicus, Arsidi used a 12-inch Cassegrain at f/48, Tech Pan film, and a 2-second exposure.

Saturn

Holding almost stationary among the stars of Sagittarius, 0.4-magnitude Saturn lies close to the Lagoon and Trifid nebulae (M8 and M20) as well as to M21, a bright open cluster. Saturn rises around midnight (standard time), but better views will come an hour or two later after it has climbed higher.

Saturn's disk appears about half as big as that of Jupiter and looks featureless by comparison. Close and careful observations show several bands crossing the planet, although Saturn's bands are less prominent than those on Jupiter.

The northern side of the rings are tipped 26° toward us, so the rings form a lovely ellipse that hides the Saturnian south pole from sight. Can you see the gauzelike crepe (or C) ring? This innermost ring is visible in backyard telescopes and appears as a faint gray smudge crossing the disk.

Uranus

It's a pity Uranus isn't brighter, because it is presently positioned between the Lagoon and Trifid nebulae among fine stellar scenery. An hour before sunrise look for Uranus about 1° north of the center of the Lagoon Nebula with your finder scope. Uranus shines at magnitude 5.6 and looks blue-green in the eyepiece; its featureless disk is 3.7″ across.

Neptune

If you can find Uranus, you can find 8th-magnitude Neptune almost as easily. Go 7° due east of Uranus to the globular cluster M22 and then 2-1/2° northeast to Neptune, which has a blue-gray disk only 2.2″ across. Neptune looks like a star in the finder scope but with 100x or more appears noticeably nonstellar.

Pluto

Even at opposition (May 1), 14th-magnitude Pluto is tough to see. You'll need a 10-inch or larger scope, a finder chart, and some dark, moonless nights to spot this slowly moving starlike point. Use the chart in the January issue or plot Pluto's positions (see box) on a copy of chart 243 of *Uranometria 2000.0*). Then adopt the same technique used to locate a minor planet: plot the field on two occasions a few days apart and look for the moving dot.

— *Robert Burnham*

Pluto's Positions

	R.A.	Dec.
March 20	14h59m43s	0°11′17″
April 1	14h58m52s	0°19′04″
10	14h57m54s	0°24′42″
20	14h57m09s	0°30′29″
30	14h56m08s	0°35′32″
May 10	14h55m05s	0°39′40″

(All positions are for 0h UT in epoch 2000.0 coordinates.)

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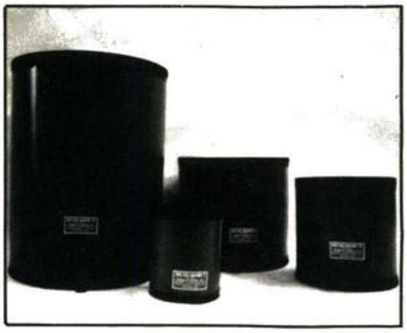

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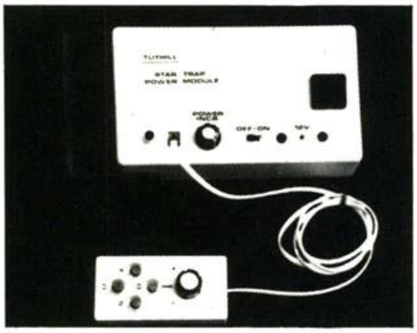

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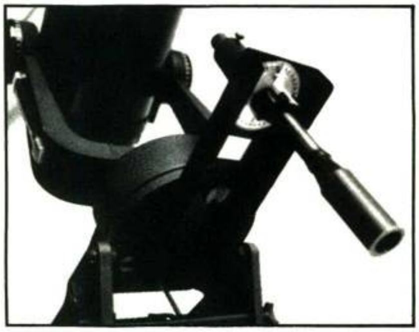

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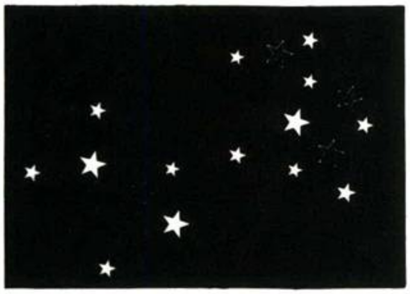

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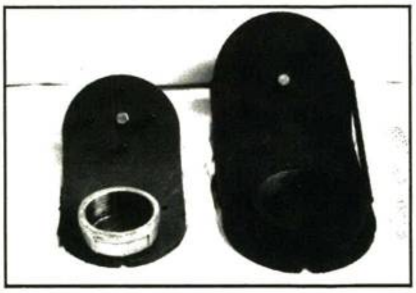

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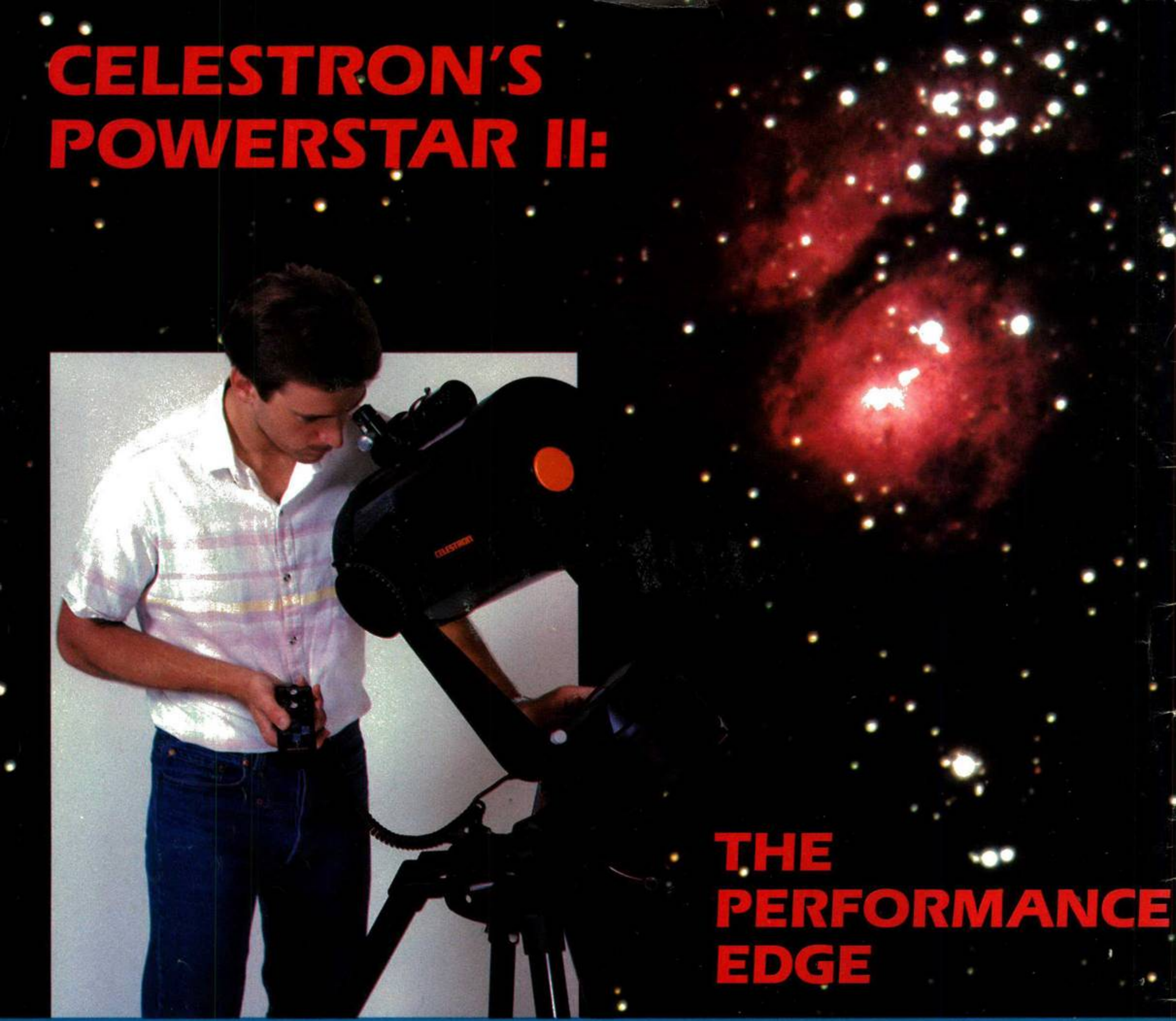

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